Albert Hafner, Ekaterina Dolbunova, Andrey Mazurkevich,
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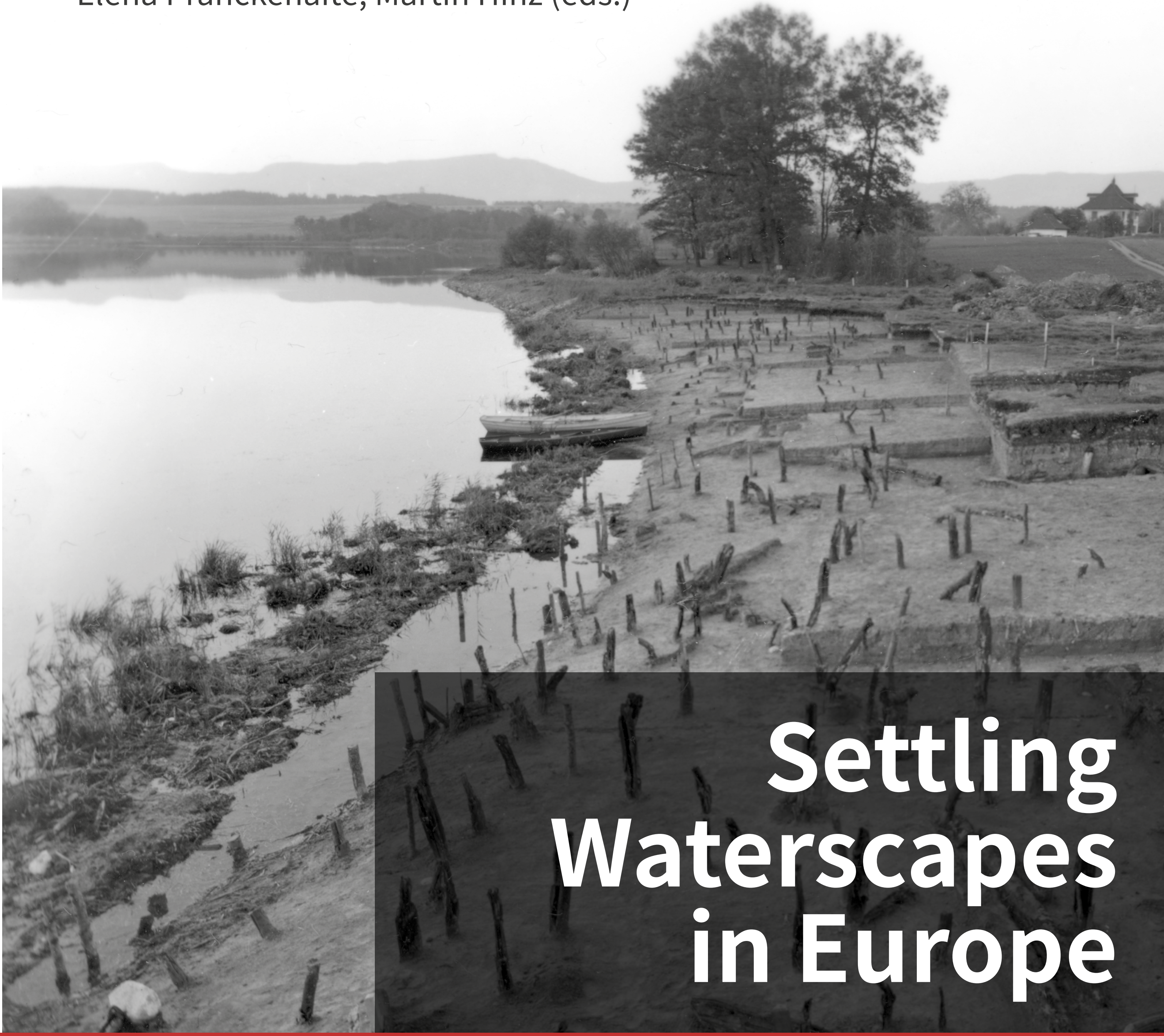

Settling Waterscapes in Europe

The Archaeology of Neolithic & Bronze Age Pile-Dwellings

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OSPA
Open Series in
Prehistoric Archaeology

Settling Waterscapes in Europe

Caroline Heitz, Martin Hinz, Mirco Brunner,
Julian Laabs, Albert Hafner

Open Series in Prehistoric Archaeology

Volume 1

OSPA
OPEN SERIES IN
PREHISTORIC ARCHAEOLOGY

UNIVERSITÄT
BERN

OSPA 1

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Edited by

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Propylaeum
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For the contribution of Drieu et al., Chapter 13 in this volume, research data are freely available online at https://doi.org/10.11588/data/5NSDVM.

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at http://dnb.dnb.de.

Propylaeum
SPECIALIZED INFORMATION SERVICE CLASSICS

Published at Propylaeum,
Heidelberg University Library 2020.

This publication is freely available under https://www.propylaeum.de (Open Access).
urn: urn:nbn:de:bsz:16-propylaeum-ebook-714-5
doi: https://doi.org/10.11588/propylaeum.714

Layout: Martin Hinz for OSPA
Cover design: Caroline Heitz for OSPA
Cover illustration: Aeschi SO, Burgäschisee Ost during the 1944 excavations.

ISBN 978-3-948465-83-4 (Hardcover)
ISBN 978-3-948465-82-7 (PDF)

ISSN 2701-2859
eISSN 2701-2867

Suggestion for citation of this work:
Albert Hafner, Ekaterina Dolbunova, Andrey Mazurkevich, Elena Pranckenaite, Martin Hinz (eds.). 2020. Settling Waterscapes in Europe : The archaeology of Neolithic and Bronze Age pile-dwellings. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum. DOI: 10.11588/propylaeum.714

Colophon
This document was typeset with the help of KOMA-Script and LaTeX using the kaobook class.

Contents

Editorial

‚Freiheit ist immer auch die Freiheit des Andersdenkenden' –
‚Freedom is always the freedom of those who think differently'

Rosa Luxemburg (1871–1919)

The freedom to think differently and to express one's thoughts is not only an indispensable principle and condition of democracy but also of any form of scientific reasoning and thus sciences and humanities as such. The need for freedom in expression beyond unequally distributed relations of power, which is emphasised in the quote of Rosa Luxemburg, a revolutionary, democratic socialist and pacifist of the European labor movement in the early 20iest century, resonates today in the current Open Science movement which is a fundamentally democratic, bottom-up enterprise of the scientific community to foster transparency, reproducibility, reusability and open communication in research (Fig. 1).[1]

1: Berlin Declaration.

With the launch of the Open Series in Prehistoric Archaeology (OSPA) by the publication of this first volume at hand we as editors have thus made a long-cherished wish and a necessity in the research landscape, a reality: The vision of the first Open Access and Open Data book series without pay wall and embargo (diamond/platinum and the gold route, see Fig. 2) that enables the peer-reviewed publication of international high-quality research in the vast field of European prehistoric archaeology! In the spirit of Open Science, both innovative, data-driven, empirical research as well as novel theoretical and methodological approaches will be made freely accessible to researchers worldwide in sustainable digital and analogue forms of publication. With this concept the series stands for free accessibility to knowledge and research results beyond financial limitation, institutional constrains or national borders, the unrestricted exchange between research communities, for the transparency and reproducibility of the research processes and hence the independence and freedom of thought.

Open Science is an umbrella term for all attempts aiming at removing the barriers to the exchange and sharing of knowledge output in every stage of the research process, including resources, methods and tools as wells as data and results. Since beginning of the 21st century, digitalisation has decisively increased and along with it the opportunities for exchange and openness in spreading scientific contents. Furthermore, the internet with all the different forms of (social) media it hosts has fundamentally changed the practical and economic realities of distributing knowledge and can be understood as part of a tech-based worldwide democratisation process. For the first time ever, a global and interactive representation of human knowledge can be constituted along with the guarantee of worldwide access. The Open Science movement aims at using these opportunities offered by the digital turn in order to make all components of the scientific process openly accessible, traceable and re-usable for the scientific community, society and the economy via the Internet.[2] Hence the Open Science movement triggers change in good scientific practice and this series, OSPA, will be part of it.

2: Swiss Academies of Arts and Science 2019.

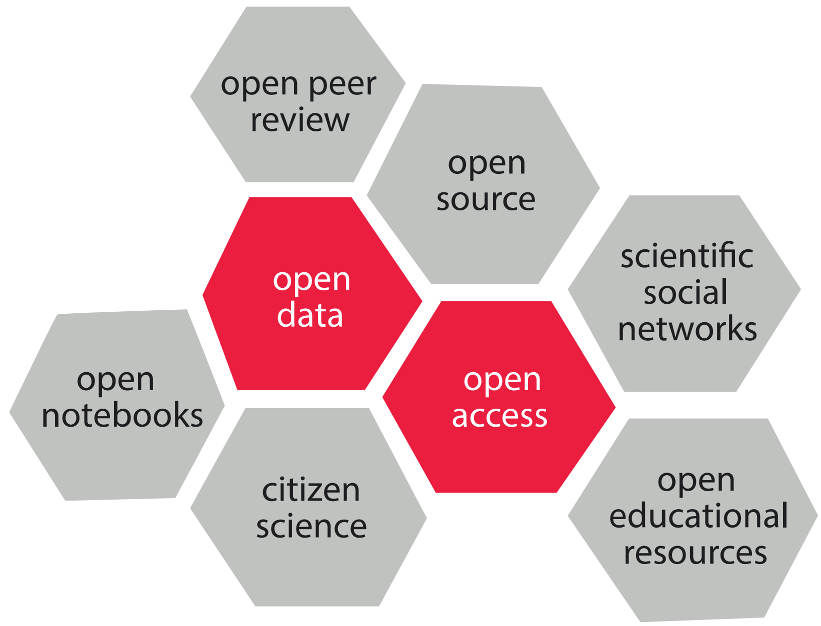

Figure 1: Elements of Open Science (after: Swiss Academies of Arts and Science 2019).

The four basic principles of Open Science are transparency, reproducibility, reusability and open communication whereby Open Access and Open Data publication are at the heart of its attempts. **Open Access** as such means already a democratization of the research process. Using **Creative Commons (CC)** licencing systems[3] ensures that authors retain the copyright of their publication with no restrictions of reusing them instead of transmitting them to the publishers. Research results thus can be better reached fostering the transnational and transdisciplinary exchange as well as the re-evaluation and the reuse of findings. This has never been more important than in the time of the Covid-19 pandemic, when open access publications lead the only possible way to continue to do research despite the restriction on travelling and to assembly in public spaces such as universities and libraries. Beyond that, OA online publications are helpful tackling another current societal challenge, that of global warming, by reducing carbon emissions per publication significantly.

3: Creative Commons.

The Open Access routes of publication are now supported or even required by research funding agencies worldwide. This policy changes the way in which research is evaluated in the long run leading to a levelling out of the imbalanced power relations. Traditionally, the success of research projects and the fundability of the researches were only measured by publications in high-ranking predatory journals that dominated the scientific community but were largely financed by public money. The Open Access publication policy has the ambition to self-empowering the researchers by regaining some control over their publications and by overcoming the dictate of a few large international publishers and thus the evaluation of early career scientists beyond financial restrictions. The Quality of research will not longer be measured by the ranking of journals or series that are governed by commercially driven publishers but its consents.

This is in line of the San Francisco **Declaration on Research Assessment (DORA)**[4] which recommends funders to consider the scientific quality,

4: Declaration on Research Assessment (DORA).

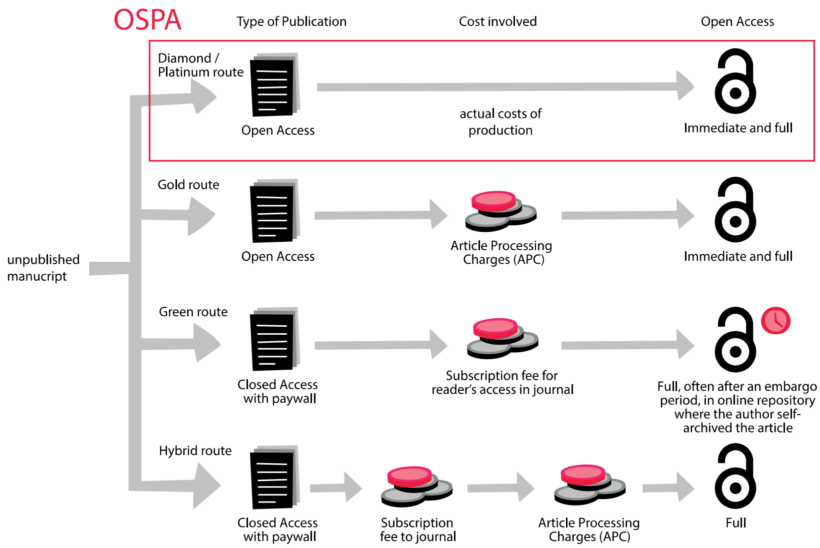

Figure 2: Open Access Models for Publications (after: Swiss Academies of Arts and Science 2019).

value and impact of their entire research output (also datasets, software etc.) in addition to research publications. Compared to former printed publications, Open Access online publication also answer to this need. Open Access schemes of publication that incorporate also an **Open Data** possibility not only allow to publish the results and interpretations of the once conducted inquiries and analyses with the citied literature. Reaching much further also the datasets with the respective metadata (data about data) and the scripts or the software used to conduct the analyses can be made freely available too on a repository by using any kind of Persistent Identifiers (PIDs), as e.g. the **DOI** (Digital Object Identifier)[5] or **ORCID**[6] . That allows other researchers to scrutinise them so that judgments can be made about the reliability and the competence of those who created the research results in terms of **Reproducible Research**.[7] Furthermore datasets can be reused in the scope of other research projects, transferred to other data bases allowing to apply new approaches of data mining in the future. Research thereby is shifted form individually conducted task of a few to a transparent open social practice of many.

5: Digital Object Identifyer (DOI).

6: Open Researcher and Contributor ID (ORCID).

7: Marwick 2018.

Coming from different fields of prehistoric archaeology, we as editors are united by the conviction that research should unfold its creative dynamic in ever growing networks of scientific communities that overcome any spatial, disciplinary, institutional, political or economic limitation. In the long run, there is hope that Open Access and Open Data publications such as the volumes of the OSPA series lead to a democratic revolution in science and humanities and hence in archaeological research too.

Caroline Heitz, Martin Hinz, Mirco Brunner, Julian Laabs and Albert Hafner

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Caroline Heitz has studied Prehistoric Archaeology, Social Anthropology and the Modern History of Eastern Europe at the University of Basel, Switzerland. She has been a research and teaching assistant at the Institute of Archaeological Sciences at the University of Bern until 2018. Within the scope of her PhD-project she has worked on the phenomena of mobility, entanglement, appropriation and transformation in Neolithic pottery from the UNESCO-World Heritage wetland sites of Lake Constance and Lake Zurich. She currently holds a postdoc-position and dresses the mutuality of human-environment relations in her reserach. Having a special interest in inter- and transdisciplinarity, she combines theoretical approaches from social anthropology with methods of archaeology and archaeometry in her research.

Martin Hinz studied Archaeology, European Ethnology and Computer Science in Germany at the Universities of Berlin and Kiel. After his PhD he worked in Kiel for several years as Assistant Coordinator for the DFG Priority Programme SPP 1400 'Early Monumentality and Social Differentiation', responsible for the editing of several collective volumes. He is also Co-Editor of the 'Journal of Neolithic Archaeology' and the 'Journal of Glacial Archaeology'. His current focus is the combination of scientific data, quantitative methods and archaeological knowledge, particularly in respect to the Neolithic and Bronze Age in Switzerland. Since 2018 he holds a position as senior researcher at the Institute for Archaeological Sciences at the University of Bern/Switzerland.

Mirco Brunner studied Prehistoric and Roman Archaeology at the University of Bern. As part of a binational *cotutelle de thèse* project between

the Universities of Bern and Kiel, he wrote his PhD thesis on mobility, networks and transformation processes of prehistoric societies in the central Alpine region. He has taught various seminars ranging from Alpine archaeology to the application of geophysical methods in fieldwork contexts. His main fields of interest are Bayesian analysis of radiocarbon dates, network analysis and multivariate statistics. He is also co-organiser of the Swiss International Summer School for Alpine Archaeology (SISA).

Julian Laabs studied Archaeology and Geography at the University of Kiel. He finished his PhD 2020 at the Institute for Archaeological Sciences at the University of Bern which was embedded in the trinational Project 'Beyond lake villages: Studying Neolithic environmental changes and human impact at small lakes in Switzerland, Germany and Austria'. Since 2020 he is employed as scientific research assistant and coordinator at the University of Kiel within the DFG Collaborative Research Centre 1266 'TransformationsDimensionen'. His main area of work is agent-based simulation-modelling applied on archaeological research questions and geostatistical analysis of Neolithic and Bronze Age datasets.

Albert Hafner studied Prehistoric Archaeology, Ethnology and Biology (Geobotany) at the Universities of Tübingen, Freiburg i.Brsg. (dissertation) and Zurich (habilitation). His dissertation dealt with the Early Bronze Age in Western Switzerland, while his habilitation research focused on high-altitude Alpine archaeology in the context of resource use strategies, mobility and climate change. He worked in the field of archaeological monument conservation, carried out large-scale rescue excavation projects in the field of underwater and wetland archaeology and was instrumental in the successful nomination of the pile dwellings of the Alpine space as UNESCO World Heritage sites. Since 2012 he holds a full professorship in Prehistoric Archaeology at the University of Bern with projects on the Neolithic and Bronze Age in Europe. Within the framework of an ERC Synergy Grant, he currently researches on lake-side settlements in the Balkans. His research interests include Holocene human-environment relationships, societal developments, burial rites, methods of underwater and alpine archaeology.

Introduction: Neolithic and Bronze Age pile dwellings in Europe. An outstanding archaeological resource with a long research tradition and broad perspectives

1

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Introduction

Research on prehistoric lakeside settlements began more than 150 years ago in Switzerland. Today, comparable settlements all over Europe belong to the best-known archaeological sites of the continent. The special conditions of the lake dwelling sites under water or waterlogged conditions in lakes and bogs led to an excellent preservation of organic materials, and settlement structures from long ago are discovered in an extraordinarily good state of preservation. Substantially preserved wooden architecture, overwhelming amounts of pottery, numerous organic implements made of wood, bark, antler and bone, textile as well as extensive plant and faunal remains made the pile dwellings welcome archaeological sources. From the 1980s onwards, high-precision dating of wooden structures by dendrochronology or a combination of dendrochronology and radiocarbon dating allowed reconstructing the architectural evolution of buildings and settlements in many cases. Precisely-dated archaeological layers help to follow the stylistic evolution of pottery and tools. The investigation of botanical and animal remains from these layers provides detailed insights into the economic conditions and long-distance relations of ancient societies. Prehistoric lakeside settlements show an extraordinarily vivid picture of the past, a glimpse into everyday life as well as reactions to and coping with climate-induced years of crisis.

Pioneering research of the 19th century

In the area around the Alps, this research has the longest history. The oldest mapping of a prehistoric lakeside settlement originates from Nidau on Lake Biel in western Switzerland. In 1811, Captain Schlatter drew a map of the town on which the Late Bronze Age site ”Steinberg” was recorded. As early as 1840, the first Bronze Age objects from Mörigen were handed over to the archaeologist Albert Jahn from Bern, after fishermen had found them in the lake. However, the pile field of Nidau was interpreted as a Roman bank fortification and the finds of Mörigen remained largely unnoticed. Isolated references in written sources from the 18th century can be traced back to observations by fishermen who tore their nets at old poles without raising historical questions. In western Switzerland, attention was drawn to the phenomenon of the submerged settlements in lakes at an early stage, albeit without being able to interpret it conclusively. Only the Zurich archaeologist Ferdinand Keller was able to provide a convincing explanation for this. In 1854, he introduced the popular term ”pile dwellings” to research. A few months earlier, in the winter of 1853/54, he had first seen piles and strange objects with his own eyes, which he undoubtedly regarded as very old. Johannes Äppli – a teacher from Obermeilen on Lake Zurich – had writ-

Hafner, A., M. Hinz, A. Mazurkevich, E. Dolbunova and E. Pranckenaite (2020). ‘Introduction: Neolithic and Bronze Age pile dwellings in Europe. An outstanding archaeological resource with a long research tradition and broad perspectives’. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 1–6. DOI: 10.11588/propylaeum.714

ten to him that workers had come across ”remnants of human activity” during the excavation of a harbour, which ”were suitable to spread unexpected light over the earliest state of the inhabitants of our region”. As was usual at that time, he and his contemporaries still considered all relics from the time before the Romans to be ”Celtic”. Although he was already known as a scientific luminary and connoisseur of the local ”Alterthümer” (antiquities), his archaeological knowledge was mainly based on the study of burial mounds. Keller's great achievement was to interpret the dark deposits and wood pieces from the bottom of Lake Zurich as settlement remains. It is undisputed today that he was inspired by ethnographic reports from the South Seas. He supported his written ideas with graphic reconstructions almost certainly based on travelogues by the French navigator Jules-Sébastien-César Dumont d'Urville (1790-1842). It can be assumed that Keller knew the German edition of the travelogue Dumont d' Urvilles, ”Entdeckungs-Reise der französischen Corvette Astrolabe”, which was published in 1836 in neighbouring Schaffhausen. Keller had already founded the "Antiquarische Gesellschaft Zürich" (Antiquarian Society of Zurich) in 1832 and since then he corresponded with archaeologically-interested people in Switzerland and abroad. Keller had spent some years as a private secretary in England and was aware of the discussions at the European level concerning the questions raised by Charles Darwin regarding the evolution of species. His large network and the knowledge acquired through it probably brought him decisive advantages in the interpretation of the first findings and later helped to spread the news of the newly-discovered European pile dwellings. The finds from 1853/54 triggered a feverish search for other pile-dwelling sites at practically all lakes around the Alps. The information was spread by Ferdinand Keller's ”Pfahlbauberichte” (pile-dwelling reports), which were disseminated in the ”Mitheilungen der Antiquarischen Gesellschaft Zürich” and appeared twelve times until 1930. In south-western Germany, the farmer and council writer Kaspar Löhle from Wangen in Baden discovered the lake dwellings on Lake Constance in 1856 and he was naturally in active contact with Ferdinand Keller. Jakob Messikommer worked with both of them and ”exploited” the pile dwellings in Robenhausen-Ried in Zurich from 1858 onwards. Later, in 1875, peat cutters in Steinhauser Ried near Bad Schussenried in Upper Swabia came across pieces of broken wooden floors and implements, which were immediately recognised as pile-dwelling finds: the first excavations in Riedschachen and Aichbühl took place in the year of the discovery in 1875 and 1877. Around the same time, in the summer of 1873, a pile field was recorded by a diver in Lake Starnberg in Bavaria. In the French-speaking part of Switzerland, with the first lowering of Jura waters in 1878, the lake level of the three large lakes Neuchâtel, Biel and Murten was lowered by more than 2m and numerous settlements were uncovered in the following years. Already since 1854, the pioneers of pile-dwelling research on Lake Biel – notary Eduard Müller from Nidau and colonel Friedrich Schwab from Biel – had maintained intensive contacts with Ferdinand Keller. However, the ”exploitation” of the sites found reached unimagined levels after the lowering of the Jura waters.

Keller's findings also attracted attention in other parts of Europe and drew scientific interest to similar local phenomena. The very first lake dwellings in the Circum-Baltic region were discovered and investigated in the second half of the 19th century. The first stage of dwellings' investigations in the present-day territory of Poland can be related to one of the main researchers, Johannes Heydeck. This determined the further historical situation of the area, in which investigations and surveys were carried out by East Prussian researchers until the 20th century. They were inspired by the settlements found in present-day Switzerland and German territories. The 1930s to 1960s are marked by an intensive accumulation of information about lake dwellings arising from conducting land-reclamation works. New examinations of prior investigations and the localisation of recent and already-known dwellings began in the 1970s. In Estonia, central European pile dwellings were discussed in the 'Learned Estonian Society'. In Russia, peat-bog sites located in the Middle Trans Urals were found in the 19th century when gold deposits were uncovered on the eastern slope of the Middle Ural Mountains. Ancient artefacts made from bones, antler, stone and pottery were found there in layers of the Shigir (Shigirsky) and Gorbunovsky peat-bog sites in the Sverdlovsk province from 1879 onwards. Some of the constructions found on these sites were interpreted as remains of platforms left on marshy areas. In 1919, the site of Modlona with dwellings on raised platforms was found in Northern Russia, and investigated in the 1930-1950s and 1970s. Since the 1960s, long term investigations have been conducted in north-western Russia, revealing the major part of Neolithic pile-dwelling sites in this area.

The evolution of excavation techniques in bog sites and under water

The first activities comprised lifting objects with primitive equipment from the lake bed or digging them at a low water level. For technical reasons, real excavations were not carried out first at the large pre-alpine lakes but rather in the bogs in the hinterland of Lake Zurich and in Upper Swabia, later also in the central Swiss Wauwilermoos bog. Here, excavation problems such as the penetration of water into the excavation sections could be more easily solved. The first large-scale excavations began in the 1920s and 1930s. In a second phase from the 1950s onwards, excavations in bog settlements were further intensified. The late-1970s brought the introduction of modern underwater archaeological methods. The invention of the regulator by J. Cousteau and technical improvements such as dry-suits allowed dives in the large pre-alpine lakes. In Switzerland as well as France and Germany, professionally-operating diving teams emerged for the first time in the following years, which were also able to carry out excavations that could meet all modern requirements for the documentation of the findings. In the 1980s, numerous large-scale excavations were carried out in connection with the expansion of the transport network and other infrastructure projects, particularly in Switzerland. In the same period, research in south-western Germany was started up again after a long break following the Second World War. Large excavations took place on Lake Constance in sites such as Hornstaad, Sipplingen, Ludwigshafen and Hagnau, as well as in the upper Swabian Federseemoor. At the same time, the breakthrough in dendrochronology took place, although the first attempts to date with tree rings date back to the period before 1940. Today, dendrochronology plays a key role in the investigation of pile dwellings, as wooden objects have been found in large numbers. More than 100,000 dendrochronological examinations have been carried out north of the Alps to date. This makes it by far the largest dendrochronological data network available for pile-dwelling research.

UNESCO World Heritage: Pile dwellings around the Alps

As part of the "Prehistoric pile dwellings around the Alps" UNESCO World Heritage nomination that succeeded in 2011, a comprehensive and uniform inventory of all known sites was compiled. Nearly 1,000 Neolithic and Bronze Age pile-dwelling sites have been inventoried and mapped in the six participating countries of Switzerland, Austria, France, Germany, Italy and Slovenia. Approximately 450 references are to be found in Switzerland. Particularly dense concentrations of settlement areas can be observed in western Switzerland in the area of the three lakes (Neuenburgersee, Bielersee and Murtensee), in the Lake Zurich area, as well as on the Swiss-German and Swiss-French border waters of Lake Constance and Lake Geneva. Together with the northern foothills of the Alps, these two of central Europe's largest inland waters form the core zone of the "pile-dwellings" phenomenon. This continues to the north with the numerous moor settlements in Upper Swabia in Baden-Württemberg, especially around the Federsee and to the east, the sites at the lakes of the Bavarian and Upper Austrian foothills of the Alps. A special geographic location is occupied by the sites on the Jura mountains, which are located far into alpine valleys at the French lakes. Comparable small regions are also known in northern Italy. However, most of the sites found here are located in the lower part of Lake Garda. In Slovenia, pile dwellings are concentrated in the extensive moorland area of Ljubljansko Barje.

However, it is clear that the phenomenon of pile-dwelling is not limited to this Circum-Alpine area, but rather it extends far beyond it. Intensive research in the east and west of the continent has come together in recent years and now makes it possible to advance the inquiry on a pan-European basis. This volume – which is intended as a cooperative project and covers in equal parts the area of the Circum-Alpine pile-dwelling horizon and contrasts it with the rich findings from Estonia, Belarus, Russia, Macedonia and Greece – is not least dedicated to this task. Thereby, the individual contributions encompass a wide variety of facets in terms of investigating pile dwellings.

In this book

In the opening, *Maili Roio* introduces the situation at Lake Valgjärv of Koorküla, as well as posing the question of whether the finds of piles at lakes Kunda and Tamula should not be placed in the same context as the Lake Valgjärv finds that are commonly referred to as pile dwellings. With the two contributions of author teams around *Andrej Mazurkevich*, we turn to the Russian situation. The first article presents the site Serteya II in the Lovat-Dvina basin. Based on the finds and features, he succeeds in drawing a dynamic seasonal picture of the activities, which can be achieved almost exclusively by wetland archaeology. The second contribution deals with the underwater investigations in Dubokray, as well as the geophysical prospections in Lake Sennitsa. Thanks to a combination of magnetometric surveys and the use of sonar and georadars, it was possible to locate a large number of potential excavation sites and obtain a precise overview of the distribution of wooden and stone constructions. The project presented by *Henny Piezonka et al.* is a German-Russian cooperation and it investigates the rich legacy of the northern bank of River

Vologda, the Veksa site. The complex picture that this site offers and the interpretation of the wooden constructions can certainly only be disentangled by means of the close integration of scientific investigation methods, as is also the case in this research project. In the following, *Maxim Charniauski* presents the Kryvina peat bog, which – with its 4000-year settlement history – represents a unique window into the Neolithic and the Bronze Age in the Belarusian Lake District.

With the following two contributions, we move into the Balkan region. *Goce Naumov* offers an overview of the situation in general and faces apparent difficulties that arise when departing from the 'classical' area of the pile-dwelling research. He places wet soil archaeology next to 'dry-land' archaeology, and postulates that one must assume more of a network between settlements in both domains and perceive these two together to truly understand the Neolithic situation in the Balkans. *Tryfon Giagkoulis* deals with a specific case study in his analysis of the situation of the lakeside settlement Anarghiri IXb in western Macedonia. The structural wooden elements found here represent a unique situation for Greek archaeology. Together with further archaeological analyses, they allow making statements about the settlement structure and woodland management for the first time, and – in the long run – they form the starting point for establishing a dendrochronology of the southern Balkan region.

Of course, one of the great opportunities of wetland archaeology is organic conservation. In their contribution to plant economics at the site of Zürich-Parkhaus Opéra, *Ferran Antolín et al.* prove that archaeobotanical research can still lead to new insights even where this potential has already been used for a long time. Particularly regarding a quantitative reconstruction of the diet, new possibilities are opening up that can contribute to a better understanding of the embedding of lake inhabitants in their environment. Together, the three following contributions refer to the "Beyond lake villages" project (2015-2019), which tries to better understand the background of the lake shore settlements by focusing on the sites beyond the direct lake shores. This project has a trinational structure, whereby Swiss, German and Austrian scientists cooperate to achieve the common goal. *Albert Hafner et al.* introduces the joint project and describes the research around the Swiss Burgäschisee, as well as the interconnected archaeological and paleoecological investigations there. By combining proxies for vegetation and fire dynamics (pollen data) with a modelling of population density and land use, the archaeological information obtained from the lakeshore settlements can be integrated into an overall picture of settlement activities. *Mainberger et al.* investigate the situation in the south-west German alpine foreland. Here, again onsite and offsite studies are closely interwoven, with palaeobotany more strongly in the foreground. In the context of geomorphological and palaeohydrological studies, the economic situation on the lake shores can be assessed and the integration of the working area into the exchange networks with the neighbouring regions can be demonstrated, which suggests a key position within the central European distribution system. Finally, as Austrian project partners, *Kowarik et al.* explore the Attersee-Mondsee region in the context of the common goals of land use and human-environmental relations. As in the previous contribution, the mobility of Neolithic communities plays an important role. GIS methods are used to investigate the accessibility of the terrain and the reconstructed catchments of the settlement sites, as well as modelling their viewsheds. The applied methods form important tools for the interpretation of past patterns of action and choices. The volume is rounded off by *Drieu et al.*, with their contribution to pottery use in Clairvaux XIV, in which the use of vessels is investigated by means of multiple approaches and the economy thus appears in high resolution at a microscopic level. This allows drawing conclusions about the use of natural resources at the site, which would otherwise remain closed. The authors can diachronically demonstrate a highly diverse use of different resource areas and thus demonstrate that the inhabitants of the lakeside settlement may have possessed a high adaptation potential to changing environmental conditions.

Despite the rich finds and the spectacular results of the excavations of the last 25 years in all parts of Europe – to which this volume also testifies – it should not be forgotten that the pile dwellings are extremely fragile monuments that need to be specially protected. In practically all pile-dwelling regions, the erosion of the shallow water zone at the large lakes leads to a permanent loss of archaeological substance. Conversely, for years sites found in bogs have been subject to a phenomenon that can be observed everywhere, which results from the lowering of groundwater levels by agriculture. The conservation efforts to preserve the lake dwellings in the long term are a challenge for present and future generations of archaeologists. By publishing the results of our work in this volume, we hope that we can contribute to raising awareness of the uniqueness of pile dwellings as a source of archaeological knowledge that must be protected and preserved.

Archaeological excavations from the past with new interpretations

2

Maili Roio[1]

1 – National Heritage Board of Estonia

Introduction

In the 19th century, research on pile dwellings also made a start in the Baltic countries. Similar to many other places in Europe, the discovery in Lake Zürich in Switzerland by Ferdinand Keller also inspired discussions about prehistoric pile dwellings in academic circles here (Speck 1981). In Estonia, the subject of central European pile dwellings was introduced at the beginning of 1866 at the Learned Estonian Society connecting the intellectuals of Tartu (Engelmann 1866, 1–4). At the same time when the number of discoveries of pile dwellings significantly increased in Europe, the existence of the few possible lake settlements in the Baltics was questioned (Grewingk 1880; Schiemann 1880; Weyrich 1880). For a long time, researchers depended on the opinion of Constantin Gewingk, professor of mineralogy of the University of Tartu and an amateur archaeologist. According to his standpoint, there are few reasons to build prehistoric pile dwellings at our latitude, since the lakes here are covered with ice during lengthy seasons, thus not providing sufficient protection for a significant part of the year (Grewingk 1879, p. 176). Since professor Grewingk was an uncontested authority in both Estonian as well as Latvian academic circles, his reasons were considered adequate and interest in pile dwellings decreased for the time being (see Roio 2003).

At present, the only construction remains of a pile settlement in Estonia have been ascertained in Lake Valgjärv of Koorküla. Despite the fact that the lake settlement has allegedly already been studied since 1640 (see Hupel 1782, pp. 331–2), the existence of the prehistoric pile dwelling in the bottom of the lake was only determined in 1958 (Selirand 1960). Lake Valgjärv of Koorküla is archaeologically exceptional because the remains of piles belong to dwellings from different periods (see Roio 2006, 2007; Virtanen 2012).

Next to Lake Valgjärv of Koorküla, several prehistoric sites are known from Estonian wetlands, the excavations of which have yielded collections of piles. The kind of information exists for the two prominent Stone Age settlement sites in Kunda and Tamula (see Grewingk 1886; Jaanits et al. 1982).

In addition to Lake Valgjärv of Koorküla, this article discusses the pile remains from the find places by the Kunda prehistoric lake and Tamula prehistoric settlement sites and their research questions. Since the studies of these sites began fifty or more years ago, the preserved archaeological material has been too randomly and inaccurately described to understand the find context of the piles. Nevertheless, it is sufficient to question the long-established interpretations.

Roio, M. (2020). 'Archaeological excavations from the past with new interpretations'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 7–16. DOI: 10.11588/propylaeum.714

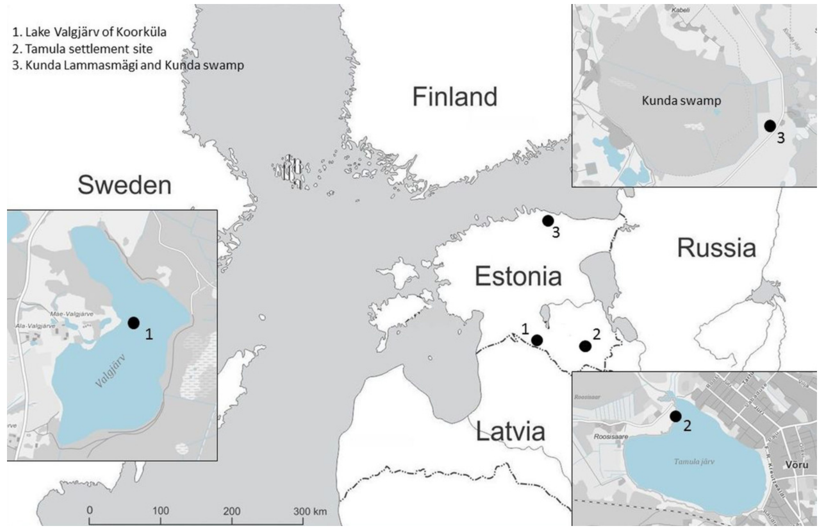

Figure 1: Map showing the places mentioned in the text. Image: Maili Roio.

Lake Valgjärv of Koorküla

The lakes of Koorküla are situated in the southern Estonian moraine landscape, demarcated by valleys and including about twenty lakes (Figure 1). Lake Valgjärv is the largest and most well known lake, at approximately 44 hectares with a mean depth of 8 m and a maximal depth of 26 m (Mäemets 1968, p. 396). The remains of log buildings are situated on the area of approximately 700 m^2 square at a depth of 1–4 m on an underwater ridge that proceeds from the tip of a peninsula in the central part of the western shore of the lake (Selirand 1960, p. 271). Folktales know well a tragic story of the origin of the lake, which was allegedly written down by monk Siegbert of Riga in his Livonian Chronicle in 1489. According to the story, around 1300 an estate owner married his sister, as a result of which the lake flooded the manor (Hupel 1782, pp. 331–2).

The legend of the origin of Lake Valgjärv of Koorküla has inspired and influenced different scholars across the ages. According to a folktale, already in 1640 the local estate owner Wolfgang Heinrich von Anrep tried to find the lost treasure at the bottom of the lake, summoning divers from Russia for the task. The divers allegedly brought up tin, copper, and wooden household objects, although after the discovery of a costly find they secretly left with it. According to some records, the number of divers called by von Anrep reached ninety and local people were also incorporated, who partly fled to Russia together with the divers (see Hupel 1782, pp. 331–2; Rambach 1818, p. 200). While this number of divers seems unrealistic, the endeavour could have still been monumental and therefore it has found its place in the oral tradition.

The first expedition of divers collecting finds from the lake was followed by several new local inspections by different researchers and other interested people in the subsequent centuries (Roio 2003, 2007). Serious research only started in 1958 with the expedition led by Selirand, which finally proved the presence of a pile dwelling at the bottom of the lake (Figure 2) (Roio 2006; Selirand 1960, pp. 270–2).

Figure 2: Getting ready for the first dive to the remains of the lake settlement in Lake Valgjärv of Koorküla in 1958. AI fk 6795 Valgjärve.

Neolithic settlement

A part of the remains of wooden construction in the bottom of the aforementioned lake derive from the Stone Age. Sherds of Late Combed Ware were discovered by Selirand on a survey trip to the lake in 1984, during which he found a total of twenty-seven sherds that may possibly belong to one and the same vessel. The fragments were found in the western part of the main structural remains (Selirand 1986, p. 2). Proof that the pole remains belonged to the same period as the pottery that had been discovered was provided after an analysis of the timber samples. According to the radiocarbon and dendrochronological dates, the Neolithic settlement site derives from approximately 3300–3200 cal BC (see Roio 2007; Virtanen 2012).

The Pre-Roman Iron Age

In 1989, two samples for ^{14}C analyses were taken from the unmapped pile group lying 40 m to the northeast of the main building remains investigated, whereby the results suggest the period of the 4th–2nd centuries BC (Roio 2003). Subsequently, two dendrochronological dates have been obtained from samples taken in 2003, which offered 313–246 BC as a result (Virtanen 2012). Thus, researchers have now collected sufficiently trustworthy dates to indicate activity in the later 1st millennium BC. This part of the underwater site has rarely been studied, and finds that would correspond to the above dates have not been detected, aside from a single metal ring that is supposed to originate from the same period (see Virtanen 2012, p. 64).

2nd half of the 1st millennium AD

The next settlement stage has been dated by both radiocarbon and dendrochronological analyses — as well as find material — to the 7th–9th century (Roio 2003, 2006, 2007; Virtanen 2012). The building remains of this period have been most thoroughly studied and published. In addition, the remains of a bridge running from the western shore of the lake to the north-western corner of the construction remains have been ascertained (Selirand. 1990, p. 3). Hand-moulded pottery from the 2nd half of the 1st millennium AD is the most numerous group of finds from the pile dwelling, with a total of more than 300 fragments (Roio 2007, p. 29). Until now, the only wooden artefact from this period is a hook, which is probably connected to forest-based apiculture. The shaft of the wooden hook has a hole in it and a groove in its inner side. The excavations of Āraiši lake settlement yielded three main components of the lifting construction used in the forest-based apiculture: a hook, a beekeeper's swing and a climbing rope (see Apals et al. 2001, 324–6, fig. 226).

The research questions of Lake Valgjärv of Koorküla

During the long research history of Lake Valgjärv of Koorküla, it has never been questioned that there are underwater building remains in the bottom of the lake. This was conditioned by the fact that the construction remains could be observed from the boat while riding on the lake. The main question in the 19th century was whether the remnants were historical manor ruins or remains of prehistoric pile dwellings. Since the latter were — according to Grewingk — out of question at our latitude, the research focus of Selirand — who led the expedition in 1958 — was also to either ascertain the existence of manor ruins or prove that the story had been fabricated (Selirand 1958). After the fieldwork of Selirand, the main interpretation of the pile dwellings of Lake Valgjärv of Koorküla was that there is a unique 6th–7th century fortified settlement in the lake (e.g. Jaanits et al. 1982, p. 266; Selirand 1986, p. 352). Even the adding of comb ware sherds to the find material in 1984 did not prompt discussions of the possibility of a Stone Age pile dwelling in the lake. According to Selirand, the water level of the lake was considerably lower during the Neolithic and the habitants found a suitable camp site on the peninsula that extended to the lake but was later inundated (Selirand 1986, p. 353, 1994). The results of the timber samples already taken by the Estonian Maritime Museum in 1989 — adding pole remains from the Pre-Roman Iron Age to the finds — were only published for the first time in 2003 (Roio 2003).

The archaeological material from Lake Valgjärv of Koorküla has remained relatively one-sided compared with the other wetland settlement sites, especially if the fact is considered that the lake has been used for living during three different periods. Apparently, the long so-called research history of the lake that — according to written sources — started in 1640 by removing artefacts from the bottom of the lake and continued for several centuries has its part to play. On the other hand, until now no excavations have taken place by the groups of poles that are located a little further from the visually observable structure. Only the ends of these poles stick out from the lake bottom.

Kunda prehistoric lake

In the 1870s, marl started to be mined for the cement factory of Kunda and during the course of the works prehistoric bone artefacts were dis-

Figure 3: Kunda Lammasmägi. Photo: Maili Roio 2013.

covered. A wide lake approximately 4 km long and 1–3 km with a low water level existed here on the place of modern mining area and its surroundings during the first half of the Mesolithic. The Kunda Lammasmägi settlement site — which gave its name to the Mesolithic Kunda Culture — is located in the south-eastern corner of the former lake and is stretched across an area of 100×70 m (Figure 3). The settlement site on the island in the former lake was discovered by C. Grewingk, who organised a test excavation here in 1886. The lake probably already swamped in the Mesolithic and peat was partly formed on the occupation layer of the settlement site. These peat layers created good conditions for the preservation of bone and antler artefacts, whereby spearheads, harpoons, arrowheads, ice picks, adzes, awls, axe heads, etc. were found. Stone tools and debris from their production were also gathered from the settlement site. The artefacts found on the bottom of the lake were interpreted as tools lost while fishing (see Grewingk 1882; Jaanits et al. 1982; Kriiska and Roio 2011).

Based on animal bones, dates that cover a long time span from 8700–4950 cal BC (Åkerlund et al. 1996, p. 266) and the location of the site, fluctuations in the water level and the character of occupation layer, it has been suggested that Lammasmägi was inhabited seasonally, whereas in different periods the site might have been used in different seasons (see Lõugas 1996, p. 290; Moora 1998, p. 65).

In the course of mining, jewellery from the Middle Iron Age (450–800 AD) and a strike-a-light were found. They were suggested to derive from a wealth deposit (Jaanits et al. 1982, p. 283). In the course of excavations in the Kunda swamp, mainly pine and oak poles were found, which were interpreted as fishing weirs (Grewingk 1886, pp. 179–80, 1887, pp. 167–8). The first stakes were found in Kunda swamp in autumn of 1885. The find was described by professor Grewingk based on samples and information sent to him by the director of the Kunda cement factory Viktor Lieven. The stakes were revealed in the northern part of the former lake, situating up to 2 m from each other. Sodden and friable stakes were 1–1.3 m long. One of the pine stakes sent to Grewingk was 110 cm long and with a diameter of 6 cm. The delivery also included a 50 cm long and 45–55 cm thick oak branch (Grewingk 1886, pp. 77–9).

Other piles were unearthed during the mining in the summer of 1886, when Grewingk himself was at the site and made notes about the find. According to the description, many wooden piles probably used in fishing were found in the northern part of the mining area. He counted altogether ten groups of stakes, which as a rule were located not very tightly next to each other and ran in two rows separated by 1.2–2 m. The longest pile found from the marl was 180 cm long. Grewingk included an example of an unearthed stake with the length of 57 cm and diameter of 6.2 cm. In addition, poles as thick as an arm that barely stuck out from the swampy soil also in two rows were allegedly detected on the shore of the neighbouring lake of the Mõisa swamp (Grewingk 1887, pp. 166–7).

In spring of 1936, the local people found a timber trackway of vertical logs in the swamp (the swamp below Lammamägi), which connects Lammasmägi to the surroundings ('Virumaal leiti püstpalkidest muinastee' 1936). In the same and the next year, Richard Indreko carried out archaeological excavations at Kunda Lammasmägi, although unfortunately he could not confirm the existence of a bridge or a trackway during his fieldwork.

In 1949, archaeological excavations led by Lembit Jaanits took place on the headland in the north-eastern pouch of Lake Kunda. The find material gathered from the 10 m long and 2 m wide excavation pit was very scarce, including only a molar tooth of an herbivorous animal and a fragment of a grinding stone. In addition, ends of stakes were found at a depth of 15–25 cm, which — as L. Jaanits suggested — were hewn with an iron axe. Jaanits chose the location of the excavation by using phosphate analysis. Since only a few archaeological finds were gathered from the excavation, Jaanits supposed that the high phosphate content of the soil on the eastern shore of the prehistoric lake was connected with the Iron Age or later habitation (Jaanits 1949). He neither presented the number, location or measurements of the stakes nor discussed their function in the report.

The research questions of the prehistoric lake of Kunda

The finds unearthed during the mining activities of the prehistoric lake of Kunda are treated in archaeological literature as stray finds. In other words, we are dealing with artefacts lost while fishing. At the same time, it should be taken into account that not all finds were noticed during mining and only the most remarkable artefacts were collected. In addition to fishing tools, the find material includes other artefacts like an arrowhead, wild boar fang, and angle points with slanting edge (see Grewingk 1882). Moreover, the Stone Age stray finds from Lake Peipsi were relatively recently still regarded as artefacts lost while fishing. In fact, we are mostly dealing with find material from inundated Stone Age settlement sites and in some cases also burial sites (see Roio et al. 2016).

However, the identification of find material and stakes is problematic. It can neither be confirmed nor refuted that the piles and finds were located together. It should be taken into account that large areas were not opened at the same time and it cannot be determined whether the two rows of stakes were observable at once with a few more rows added in later years or if the rows of stakes were well-defined groups forming clearly demarcated structures. Unfortunately, these questions cannot be answered, although it is clear that many groups of stakes could be found in the marl mining area in Kunda and at least some could have originated from the same period as the Stone Age finds. Some of the pole remains could also be connected with the potential Middle Iron Age habitation; for example, the piles found during the excavation led by Jaanits rested only at a depth of 15–25 cm and had probably been hewn with an iron axe.

We still know relatively little about the early settlement of the prehistoric lake of Kunda as a whole. The last investigation at the Stone Age settlement site of Kunda Lammasmägi took place in 2014 and the most recent in-depth research was completed in 2014 as the master's thesis of Kristjan Sander (see Sander 2014). In his study, Sander emphasises the need to proceed from the investigation of Lammasmägi to the micro-regional archaeology of the prehistoric lake of Kunda and the discerning of different phases in the habitation of the settlement site based on the find material from Lammasmägi and the stratigraphy of the site. He also stressed that uniting these into a new, more complete picture — finding correlation between other settlement sites of the Kunda prehistoric lake and the habitation phases of Lammasmägi — requires extensive fieldwork in the future (Sander 2014, p. 4). Without new fieldwork, the character of the groups of piles in the prehistoric lake of Kunda cannot be clarified.

Lake Tamula

There is a Stone Age settlement site on a small low cape on the western shore of Lake Tamula in south-eastern Estonia that in archaeological literature has come to be known as the Tamula I settlement site. The Tamula I settlement site was discovered in 1938 by accident by a local photographer Ida Kepnik, who — while looking for her lost ring — found single bones from the shallow beach water. The discovery aroused her attention and she started to systematically collect finds, gathering a couple of large boxes full of various bones and artefacts (Indreko 1939).

The Tamula I settlement site was archaeologically excavated in 1938 and 1942–1943 under the leadership of Indreko, in 1946 by Harri Moora and in 1955–56, 1961, 1968 and 1988–89 by Jaanits, whereby altogether 650 m^2 of the site has been excavated (e.g. Indreko 1945, 1948; Jaanits 1984, 1988).

In the Tamula I settlement site, the occupation layer was formed directly on peat and later was covered by peat again, which indicates that a swampy area was chosen for living (Figure 4). Twenty-five burials were unearthed in the peat layer of the settlement site (Jaanits 1988, p. 218). Two archaeological cultures — Late Combed Ware and Corded Ware — are represented in the ceramic material. According to radiocarbon dating, the place was used as a dwelling and/or a burial site from 4600 to 2000 cal BC (see Kriiska and Roio 2011, p. 62).

Piles of pine, black alder, and other kinds of trees were found in Tamula, which were interpreted as the remains of light above-ground dwellings (Jaanits et al. 1982, p. 82; Jaanits 1984, p. 184). The piles are concentrated in the lakeside part of the settlement site. The ^{14}C analyses of a pile from the occupation layer gave the result of 3600±180 cal BC (Lõugas 1996, p. 407). Unfortunately, the exact find spot of the pile used for the sample could not be located.

Figure 4: Tamula I settlement site. The shore of the lake is still swampy. Photo: Maili Roio 2007.

Research questions

The small cape chosen for the settlement was freed from water in the Atlantic period and peat started to form on it. During the dry Subboreal period, the water level in the lake further decreased, thus making the area suitable for living. At some point, the water level rose again and inundated the tip of the cape. The water destroyed part of the occupation layer and a number of artefacts ended up in gyttja (Jaanits et al. 1982, p. 78). It was ascertained that archaeological finds can be detected as far as 15 m from the shore (Ots and Roio 2013).

The piles in Tamula were interpreted as belonging to the above-ground dwellings, although not a single ground plan of a dwelling has been successfully detected. During the time of habitation, the site was rather a damp area. In these cases, dwellings on piles were used at the time, similar to those that we now know from Lake Valgjärv of Koorküla, one of the settlement phases that coincides with the habitation period of Tamula.

Summary

The dim view taken in the 19th century about the possibility of finding pile dwellings has later significantly hindered the locating of respective sites and the interpretation of piles. Unfortunately, only one-sided information about groups of stakes in Kunda and Tamula has preserved, which allows no final conclusions. Alas, the researchers of the site have not considered it necessary to describe the find context of the piles with sufficient accuracy. However, we should pay attention to the problem in the treatments completed so far.

Lake Valgjärv of Koorküla was already periodically used as a dwelling site since the Neolithic, whereas always one and the same part of the lake was used. The northern part of the Kunda prehistoric lake yielded plenty of groups of piles, which were regarded as the remains of fishing weirs. Assemblies of piles were also found in the neighbouring swamp. Considering the find context of the piles — i.e. the depth of their location — it was

suggested that the majority of the stakes unearthed in the 19th century belong to the Stone Age. As a supporting argument for the usage of the poles as fishing weirs, it was highlighted that the diameter of some of the piles was approximately 6 cm. Unfortunately, we only know the diameter of a couple of stakes and one oak branch, in case of which it is unclear whether identifiable traces of working were discerned at all. In addition to the problems with the interpretation of piles, it is also doubtful that the artefacts found during mining marl are accidental, e.g. lost while fishing. Considering the diversity of finds and the presence of piles and other wooden elements, it is more likely that at least a part of the prehistoric settlement layer was destroyed in the northern part of the lake.

A relatively large area has been excavated at the Tamula settlement site, although unfortunately the documentation of piles remained inadequate during the investigation. Moreover, it is hardly satisfactory to estimate the using time of the piles solely based on the radiocarbon analysis of a single pile.

All three discussed sites have a special status in Estonian archaeology with their long research history, although in the light of the research questions presented in the article the investigations conducted thus far cannot be regarded sufficient. All three sites require additional fieldwork, thorough analysis, radiocarbon and — if possible —dendrochronological dates to specify the periods of their using, as well as palaeogeographical reconstruction and association with the geological development of the waterbodies.

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Landscape, seasonality and natural resources use in the 3rd millennium BC by pile-dwelling communities (NW Russia)

3

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Introduction

Particularities of the landscape surrounding the Middle and Late Neolithic sites in the Dnepr-Dvina region were first studied in the 1980s by A.M. Miklyaev and P.M. Dolukhanov. It was suggested that the choice of the place for Stone Age settlements was determined by a proximity to three types of landscapes: moraine plateaus overgrown by mixed deciduous forests, fluvioglacial plains overgrown by mixed forests with a dominance of pine, as well as lakes, swamps and weakly-developed river valleys (Dolukhanov and Mazurkevich 2000; Dolukhanov and Miklyayev 1986, 1983). It was conditioned by several factors (Dolukhanov and Miklyayev 1986, 1983), including the choice of the territories where animals dwelt during different periods of time in the vicinity of the whole-year-inhabited site. Although the hunter-fisher-gathering economy remained the basis of the ancient economy in this region for a long period from the 7th to the 3rd millennium BC (Early–Late Neolithic), different hunter-gathering economical models can be reconstructed for this region. A comparison of landscape particularities where Early–Late Neolithic sites were erected allows describing differences in settlement systems and landscape use based on different economic strategies. Seasonal base camps as well as temporal sites can be traced for the 7–5th millennium BC (Early Neolithic/-Subneolithic, Mazurkevich and Dolbunova 2011, 2015) in the Serteysky microregion within the Dnepr-Dvina region. Such a system of sites location might be a marker of a high seasonal and 'local' mobility, reflecting an economic model typical for small societies and the climatic/ecological conditions of the Atlantic period.

Another settlement system can be traced in the Middle Neolithic, whereby settlements became inhabited all year round and the population increased, which led to another model of economic activity (Mazurkevich and Dolbunova 2011). Changes in ideology reflected in architecture (pile-dwelling appearance) and art objects can be traced in the Middle Neolithic, along with contacts with agricultural and cattle-breeding societies (Mazurkevich 2013). Pile dwellings in general are regarded as not only a new form of architecture, but a reflection of a new way of life involving changes in ideology (Pfahlbauten 2016). However, the society inhabiting the Dnepr-Dvina region remained a highly efficient community of hunter-fisher-gatherers who rarely practised a productive economy.

Several groups of resources can be distinguished: food resources comprising gathering products, fishing and hunting, and households, aiming to supply different activities (buildings, pottery making, fishing constructions, etc.), where the season might serve as an important factor determining both the accessibility and availability of resources. It is difficult to estimate the input of each of the components in ancient economy. The latter can be regarded from the perspective of resources' accessibility and

Mazurkevich, A.N., M.V. Sablin, E.V. Dolbunova, P. Kittel, Y. Maigrot, E. Kazakov (2020). 'Landscape, seasonality and natural resources use in the 3rd millennium BC by pile-dwelling communities (NW Russia)'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 17–35. DOI: 10.11588/propylaeum.714

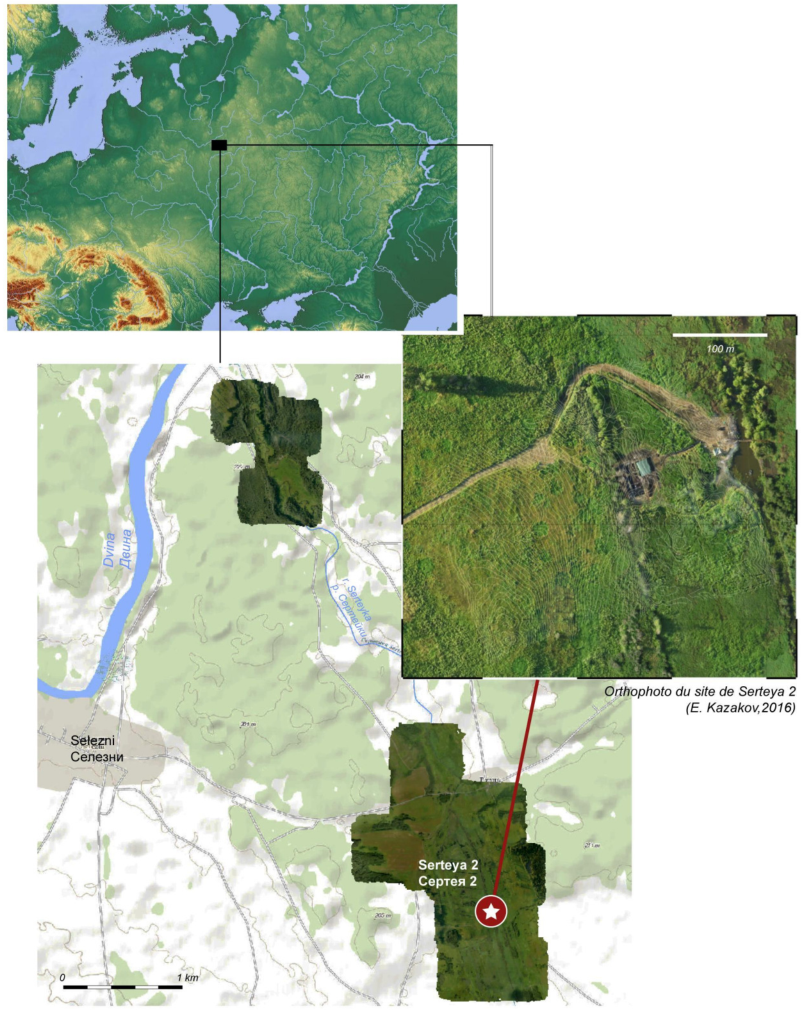

Figure 1: Location of the Serteya II site (NW Russia).

the expenses spent on their procurance, depending on the local milieu and ecological niche in each archaeological microregion. A reconstruction of the economic model of pile-dwelling site inhabitants is suggested in this article, based on household activities and the spatial distribution of available resources used by local inhabitants living in the Serteysky microregion in the middle of the 3rd millennium BC. Archaeological materials, faunal, and ichthyologic collections, palynological data, macroremains analysis, analysis of wood species, and lacustrine sediments served as the main source for the reconstruction of ancient economic activity. They were gained during an investigation of pile dwelling dated to the early/mid-3rd millennium BC Serteya II (Figure 1), as well as the study of Serteysky peat bog (Figure 2, Figure 3) (Mazurkevich et al. 2012).

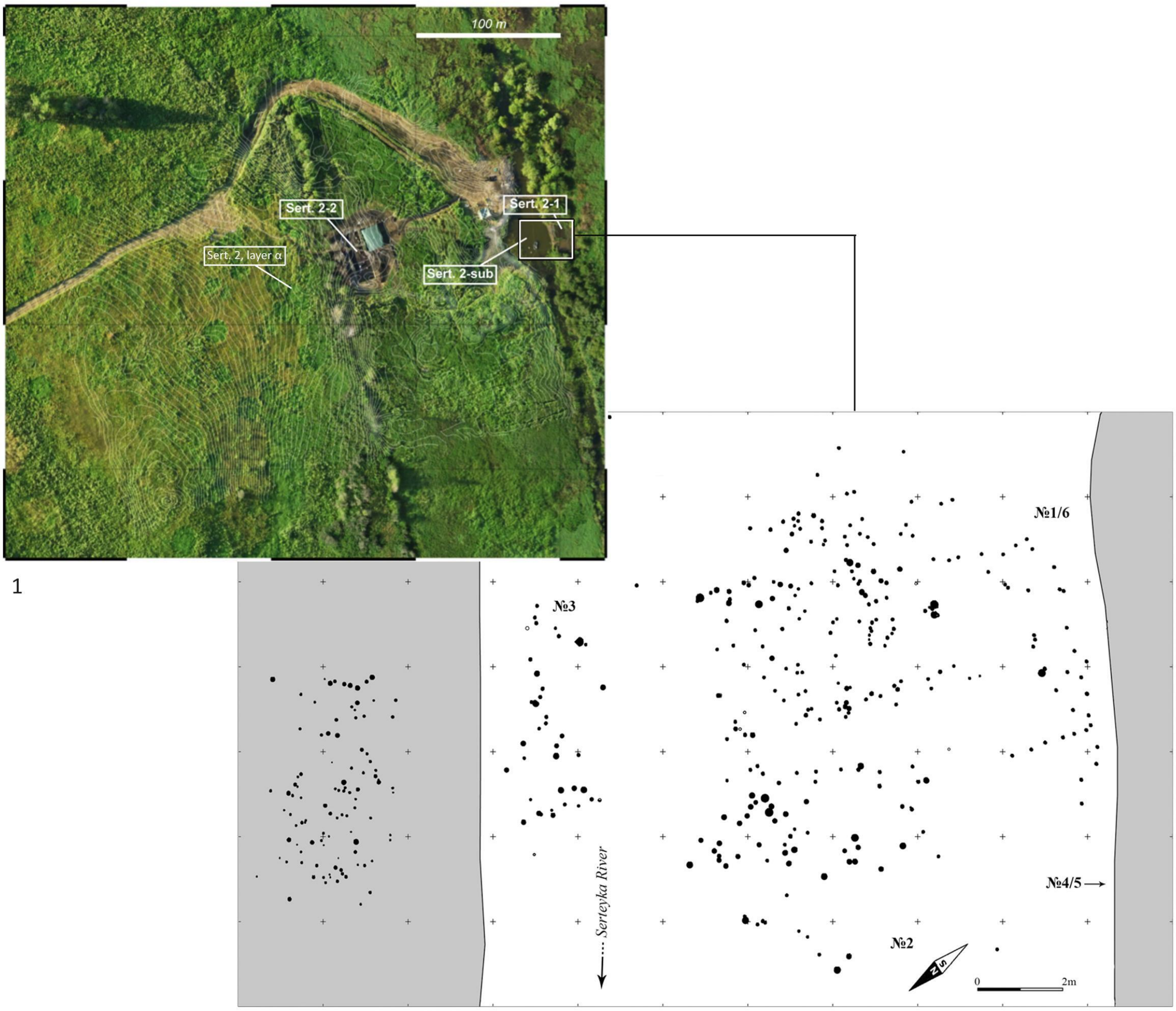

Figure 2: Piles' distribution and location of central pile-dwelling part (Sert. 2-1, sub), area with butchering zone and ground constructions (Sert. 2-2) and site on a mineral cape (Sert.2, layer α).

Landscape description

Serteysky basin is a part of a subglacial channel previously occupied by lake basins and replaced in the Holocene by a river system. Until the modern period, declining lake basins were connected by sections of streams. The Serteyka River subsequently drained all water bodies as an effect of headward erosion (Kalicki et al. 2015; Kittel et al. 2016). Nowadays, the Serteyka River flows in the Serteysky basin, elongated from the north to the south. Numerous biogenic plains within the present-day Serteyka River valley are remnants of former palaeolakes. The lakes that previously existed to the north in the Atlantic period became completely overgrown in the Subatlantic period, and the pile-dwelling site Serteya II was erected. Based on palynological and stratigraphical data from the Rudnya Serteyskaya site (Dolukhanov et al. 1989) located to the north from the Serteya II site, waterlogged areas with a forest and small rivers towards

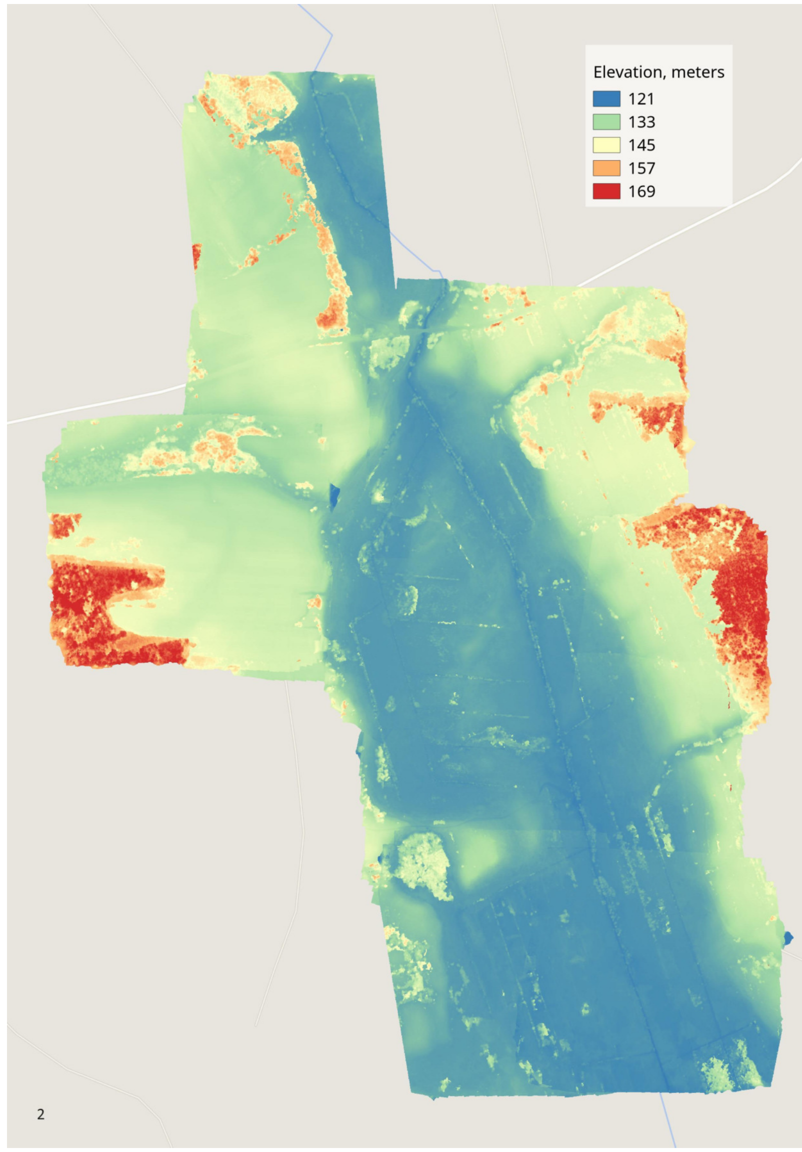

Figure 3: Digital elevation model of the Serteya II site and its surroundings.

the Western Dvina River were distributed in the Rudnya Serteyskaya palaeolake basin.

The Serteya II site is located inside the hollow basin, whose slopes are at a 27˚ angle (Figure 4). This place is located in a morainic zone, where the following forest can be reconstructed (basing on palynological data from core 62, located at the Serteya II site): coniferous trees dominating along with deciduous species and alder, whereby fir trees were replaced by alder, birch, oak and elm at the end of the Subboreal period. Fir trees almost had completely disappeared by 3200±60 BP (LU-4878), i.e. 1621–1306 BC, and forest renewal started only 200 years afterwards (Arslanov et al. 2009; Mazurkevich et al. 2012). Initially, the site was located in the zone of mixed coniferous-deciduous forest. Nearby on a slightly inclined surface of the fluvioglacial hill of the crevasses filling from the western side, there was an open woodless space, which corresponds with meadow and meadow-chernozemic soils (Aleksandrovsky 2014). Shrubs (predominantly alder) grew on the lake shores, and alternation of the wa-

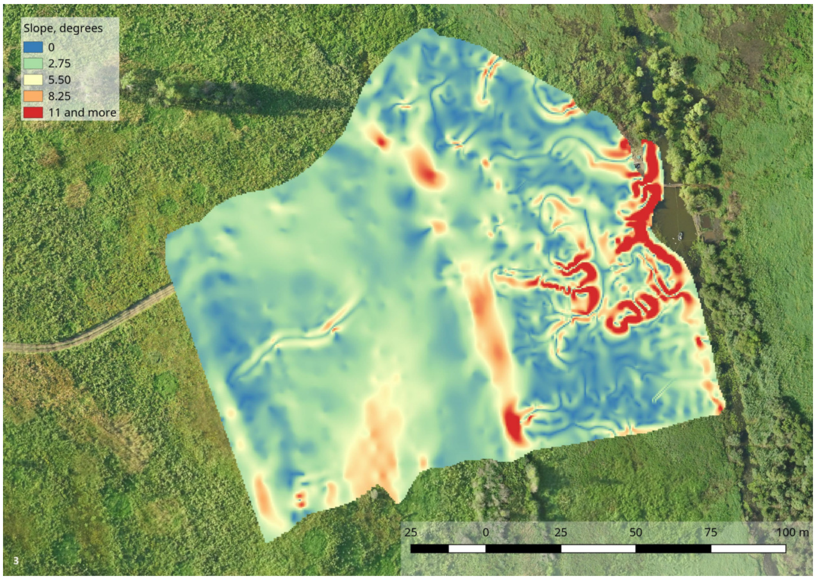

Figure 4: Corresponds to Figure 2, Slopes angle.

ter level can be traced during the Subboreal period (end of the 4th–3rd millennium BC), which led to periodic flooding of shore vegetation (Arslanov et al. 2009; Mazurkevich et al. 2012). Changes in vegetation can be traced approximately 1–1.5 km to the north of the site. Fluvioglacial sediments with coniferous-birch forests can be recorded here. Oak forest can be reconstructed in proximity, based on palynological data from the core at the Rudnya Serteyskaya site (Dolukhanov et al. 1989, Figure 1).

Settlement structure

The Serteya II site has a rather vast chronology for a pile-dwelling settlement, even taking into account a wide period provided by radiocarbon dates, which can evidence both rather long inhabitation of this site and multiple visits to this place (Mazurkevich et al. 2017). The most ancient dwelling is dated to about 2900–2570 BC. After this, the site could have been uninhabited for some time, whereby the next construction period could be dated to 2570–2330 BC. The settlement was most actively populated during 2470–2270 BC. We might suppose that during this period a small society lived here and successively constructed pile dwellings and/or reconstructed them at the same place. The Serteya II site (period of the dwellings 1/6–3 existence) might have been the only inhabited site in the middle of the 3rd millennium BC in the Serteysky archaeological microregion. The remains found at the site are attributed to Zhizhitsa culture, which was formed at the turn of the 4th–3rd millennium BC based on different cultural components (Mazurkevich et al. 2017). Material culture includes various traits typical of preceding Usviatskaya culture, Funnel Beaker culture, Globular Amphora culture, probably Corded Ware culture and the late stage of the Dnepr-Donets culture (Mazurkevich 2013). Amber artefacts provide evidence of connections with the Baltics area. Reconstruction of the economic system represented in this article was created for the time slice of the middle of the 3rd millennim BC.

Several inhabitation areas located near the eastern part of the mineral cape attributed to the Middle–Late Neolithic were traced at Serteya II (Fig-

Figure 5: Serteya II. Part of a wall (?) made of wooden treated splinters (1); wooden pile and remains of a bark floor of the dwelling #1 (2).

ure 2). More than 200 m^2 was investigated at the site. Dwelling constructions with raised floors were found 70 m from the top end of the cape. Several building horizons were distinguished in the central part within dwelling №1 (Figure 5). The cultural layer is located both under water and in peat bog. It was situated on the shore of the lake or mire and partly in the swampy area of the lake margin. Neolithic artefacts were found both below and within coarse-detritus gyttja. Based on the results of core analysis and excavations, this part of the site spreads from the modern left shore of the Serteyka River in the eastern direction, and it disappears in the western direction. Inhabited areas were distinguished at 40 m to the west from dwelling №1, near the base of the mineral cape. Another accumulation of materials was also traced on a mineral cape, where pottery similar to that found in the pile-dwelling site can be traced, named Serteya II, layer α (Figure 2).

Food resources

Animal hunting is always suggested to be the main source for food and different household activities. Analysis of faunal remains from the Serteya II site shows that elk was the main hunting species. Spatial analysis of elk bones' distribution on the site and in different constructive horizons demonstrates that butchering was conducted on the site, between the

Table 1: Animal species on the site Serteya II.

Species	Serteya II		
	species	bones	%
Beaver - *Castor fiber*	25	301	22.62
Squirrel - *Sciurus vulgaris*	4	5	0.38
Hare - *Lepus timidus*	1	1	0.07
Fox - *Vulpes vulpes*	1	6	0.45
Polecat - *Mustela putorius*	1	1	0.08
Marten - *Martes martes*	18	131	9.84
Badger - *Meles meles*	3	19	1.43
Otter - *Lutra lutra*	7	17	1.27
Lynx - *Lynx lynx*	3	3	0.23
Bear - *Ursus arctos*	6	19	1.43
Wild boar - *Sus scrofa*	8	124	9.32
Elk - *Alces alces*	31	699	52.51
Total amount	108	1326	99.63
Dog - *Canis familiaris*	2	5	0.37

dwellings or in a particular zone 40 m remote to the west. Three to five elk species were found in each constructive horizon of dwelling №1, including adults, sub-adults and young ones 3–5 months old. The latter prompts suggesting that late summer–early autumn was a hunting season. Thus, during summer hunting was conducted on marshy areas and deciduous mixed forests, located in a morainic area in proximity of the site, within a radius of 1 km. Winter elk hunting was conducted in another landscape, namely mixed coniferous forests where elk migrated. Such a landscape zone was recorded 1 km to the north, north-east, north-west and further to the Western Dvina River and Mezha River. Such a landscape can be also traced on a left shore of the Western Dvina River (urochishche Petrovsky mokh) and it continues on right shore of the Mezha River.

Wild boar is the second most important species (8 species, 2–4 for each constructive horizon/construction) (Table 1, 2). Whole or parts of carcasses of only adult species can be found on the site. Wild boar hunting was conducted throughout the whole year in mixed deciduous forests with small marshy areas and open spaces, located near the site.

The same number of bear bones was recorded (6 species, 1–2 for each constructive horizon/construction) (Table 1, 2). Remains of adult animals were found here. We might suppose that the whole carcass was not brought to the site, but rather its butchering was undertaken outside. Bear hunting was most possibly conducted during winter, whereby the places of bears' lairs might be located in deciduous forests.

The amount of fur game is rather high and prevails over 'meaty' species. However, the total number of fur animals found at the site is rather small and could not supply the needs of inhabitants of this long-term settlement neither in terms of meat or the necessary number of skins (Table 1, 2). Marten and beaver are the most widespread. Almost the whole carcasses of fur animals found on the site testify that butchering was undertaken there. These animals could have been hunted during autumn–winter, in case the main aim was fur procurement. Beaver could also be hunted for meat. Beavers jaws were used for tools utilised for wood treatment (Maigrot 2014). These animals were hunted in coastal landscapes,

Table 2: Serteya II. Animal species in Dwellings 1 and 3.

Bones	Dwelling 1										Dwelling 3								
	Beaver	Squirrel	Fox	Marten	Badger	Otter	Lynx	Bear	Wild boar	Elk	Beaver	Squirrel	Marten	Badger	Otter	Lynx	Bear	Wild boar	Elk
Cranium	7	-	-	4	2	-	1	-	4	15	7	-	5	1	1	-	-	1	1
Maxilla	2	-	-	-	-	-	-	-	1	8	-	-	-	-	-	-	-	-	2
Mandibula	1	1	-	10	2	1	-	-	3	7	4	-	8	-	-	-	-	1	11
Teeth	30	-	-	-	-	-	-	4	7	22	6	-	1	-	-	-	3	5	4
Antler	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Os costae	-	-	-	-	-	-	-	-	-	20	4	-	-	-	-	-	-	-	1
Vertebrae	17	-	-	2	15	-	-	-	-	36	3	-	4	-	-	-	-	-	16
Sacrum	1	-	-	-	-	-	-	-	-	3	1	-	-	-	-	-	-	-	-
Scapula	5	-	-	3	1	-	-	-	-	2	2	-	4	-	-	-	1	-	8
Humerus	13	-	-	7	2	-	-	-	2	11	4	-	6	-	-	1	-	1	5
Ulna	6	1	-	1	-	-	-	-	-	3	4	-	-	-	-	-	-	-	1
Radius	8	1	2	-	-	-	-	-	1	9	1	-	4	-	-	-	-	-	9
Ilium	4	-	-	2	-	-	-	-	-	5	4	-	3	-	-	-	-	-	-
Femur	17	-	-	3	-	-	-	-	1	4	6	1	4	-	-	-	-	-	3
Patella	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1
Tibia	19	-	-	3	-	1	-	-	2	6	8	-	7	-	1	-	-	1	3
Fibula	2	-	-	2	1	-	-	-	1	-	1	-	-	-	-	-	-	1	-
Carpalia/tarsalia	2	-	-	-	-	-	-	-	2	42	-	-	-	-	-	-	-	-	18
Astragalus	1	-	1	1	-	-	-	1	4	5	1	-	-	-	-	-	-	1	2
Calcaneus	2	-	-	-	-	-	-	-	1	8	1	-	-	-	-	-	-	-	3
MC/MT	8	-	-	3	-	-	-	-	4	28	4	-	1	-	1	-	-	7	13
Phalanges	6	-	3	-	-	-	-	1	6	62	2	-	-	-	-	-	-	2	46
MNI	15	2	1	5	1	1	1	2	4	14	4	1	4	1	1	1	1	2	7

Table 3: Serteya II. Birds species.

Species	bones	%
Gavia stellata	1	0.9
Anser anser	4	3.8
Anas platyrhynchos	58	54.2
Anas strepera	2	1.9
Anas penelope	4	3.8
Anas crecca	6	5.6
Anas clypeata	3	2.8
Anas sp.	1	0.9
Mergus albellus	4	3.7
Oxyura leucocephala	2	1.9
Bucephala clangula	1	0.9
Mergus sp.	1	0.9
Anatidae indet.	11	10.3
Milvus migrans	1	0.9
Tetrao urogallus	5	4.8
Galliformes indet.	1	0.9
Fulica atra	1	0.9
Gallinula chliropus	1	0.9
Total amount	**107**	**100**

including rivers, streams, which did not freeze over, with wood-shrubby vegetation and grassland vegetation on the shores and in the lake. Such zones were located within the periphery of the whole Serteysky lacustrine paleosystem. Badger indwelled on sandy and sandy loam soils in field woodlands, gulleys, the terraces of the lakes and above the slopes of the subglacial channel. Such landscapes are located approximately 1 km to the north and further on from the site. Marten, squirrel and lynx indwelled in coniferous forests, which were located near the site and further on far to the south, east and west. Weasel also indwelled there, on the margins and fells.

Birds hunting. Mostly waterfowls and partly migrant species (loon, heron, goose, river ducks, white-tailed eagle, bald-coot, etc.) were found at the site (Table 3–4) (Sablin 2014; Sablin et al. 2011). They were hunted during spring–autumn on the lakes and their shores, i.e. within a radius of 1–2 km to the south and 1 km to the north of the site. Blackcock and partridge were hunted during late autumn–early spring in small groves, field woodlands, sparse forest with berrying ground, in large river valleys, on the edges of raised bog and transition bog, as well as bottomland meadows with birch predominance. Such natural zones might be reconstructed for the northern part of the valley, probably to the east and west, at a distance of 1 km and further on in northern-eastern direction up to the Western Dvina River and Mezha River, as well as in north-western direction up to the Western Dvina River and Selezni village. Such landscapes are also located on a right shore of the Western Dvina River, at the place called urochishche Petrovsky moss.

Fishing. Analysis of ichthyologic collection was conducted by E. Lyashkevich. Fish bones were found predominantly in sand, located under the fireplace, as well as in garbage piles and pits, located within the perimeter around the dwellings. The main species include pike, perch, tench, cru-

Table 4: Fish species on the site Serteya II.

Species	bones	%
Acipenseridae indet.	2	0.01
Anguilla anguilla	8	0.05
Esox lucius	4867	38.5
Rutilus rutilus	124	1
Leuciscus idus	28	0.2
Scardinius erythrophthalmus	43	0.3
Aspius aspius	4	0.02
Tinca tinca	80	0.6
Abramis brama	21	0.2
Carassius carassius	76	0.6
Cyprinidae indet.	2809	22.2
Silurus glanis	18	0.2
Perca fluviatilis	4462	35.3
Sander lucioperca	11	0.1
Gymnocephalus cernuus	31	0.2
Percidae indet.	74	0.6
Total amount	**12658**	**100**

cian carp, roach, pike perch, bream, orfe, red-eye, eel, and catfish. Fishing was conducted within two lacustrine basins. Some fish species might have been caught during night with a pole or with nets, fish traps, and other implements. Such finds were made in a cultural layer of the site. Moreover, specialised places for fishing were uncovered, one of which was called Serteya I site, located 800 m to the north in a narrow part of the lake basin and small river (Mazurkevich et al. 2017). It was made on the shore of a small river that connected two lakes: the southern Great Serteya palaeolake basin (2.7 x 1.4 km) and northern Rudnya Serteyskaya palaeolake basin (1.1 x 0.3 km). A fence made from pine chips and a fishing net with a mesh 3.5 x 3.5 cm were found here. The main fish species were caught in nearby lakes located within the Large Serteya basin. Specifics of habitats of some fish species and particularities of the lakes during this period in the Serteya lake basin (low flow basins, streams, and rivers with silty shores) (Kul'kova and Savel'eva 2003) prompt the suggestion that catfish could not have dwelled in such water basins, and they possibly dwelled in the Western Dvina River. It is located more than 5 km away from the site, which would mean elaborating of specialised fishing activity.

Gathering products are not very numerous and they include water and forest products. Numerous shellfishes were found in garbage pits (Figure 6). They might have been gathered in the surrounded lake basins during the spring–autumn period. They could have also been used as a temper material for pottery making. A great number of *trapa natans* can be found in a cultural layer, garbage piles, and pits. It could have been gathered during August–September in the lake basins on silty ground or in lakes with a ditch or low flow water. Finds of *trapa natans* without any other evidence of a cultural layer might simply indicate zones of its growing. Water-lily grows in lakes with a ditch or low flow water, at a depth of approximately 2 m. Young roots of water-lily are edible and can be used for flour. It might have also been used as antiphlogistic. A great amount of hazelnut (parts of shells and whole ones) was found in garbage pits

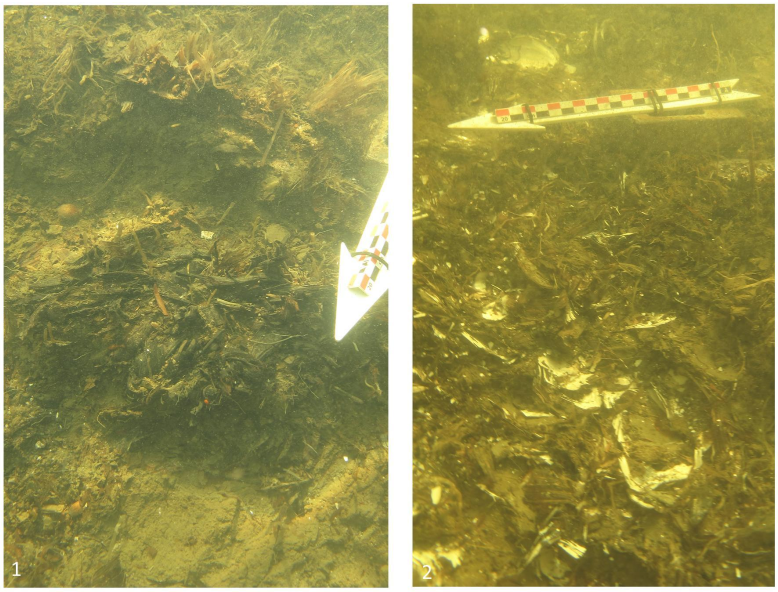

Figure 6: Serteya II. Accumulation of lime bast (1) and shell pile (2) within the dwelling #1. Underwater photo.

or the cultural layer with other food remains. Hazelnut and *trapa natans* were sometimes burnt, which might be evidence of heat treatment. Hazel might have grown on the margins of mixed, coniferous, and broad-leaved forests and gulleys. It was distributed between 500 m and several kilometres to the south, east, and west. Hazelnut could have been gathered during early autumn. Moreover, acorns can be found in garbage piles. Oak forests might have grown in the vicinity of the site (within a 1 km radius) and gathered during early autumn. Guilder grows on the margins, meadows, felling sites, and in fir-broad-leaved forests. Fruits were primarily used and they are found in cultural layers, while seeds and bark might have also been used in physiotherapy. It was gathered during second half of September and the beginning of October.

Some vegetation oils were used for cooking along with fish/meat based on lipids analysis of pottery (Kulkova et al. 2015).

Resources for household activities

Wood. Ash and other broad-leaved species were used for the construction of dwellings, and later on dwellings were made from fir (Hookk 2007). The diameter of piles was 6–8 cm, 9–11 cm, and 12–28 cm, corresponding to the wood age of 10–14, 20–45, and 70–94 years. Fir piles grew in a secondary forest with stable ecological conditions, on a waterlogged area, and in a forest under constant anthropogenic influence. Pines were taken from the forest, which was not under anthropogenic influence, and broad-leaved species grew in the forest with stable ecological conditions without anthropogenic influence or at the forest margins (Hookk 2007). Broad-leaved species (maple, oak, and ash), elm, alder, horn-beech, and beech were used as the main fuel material based on anthrocological analysis, with a very small amount of fir, pine and birch (Aleksandrovsky 2014).

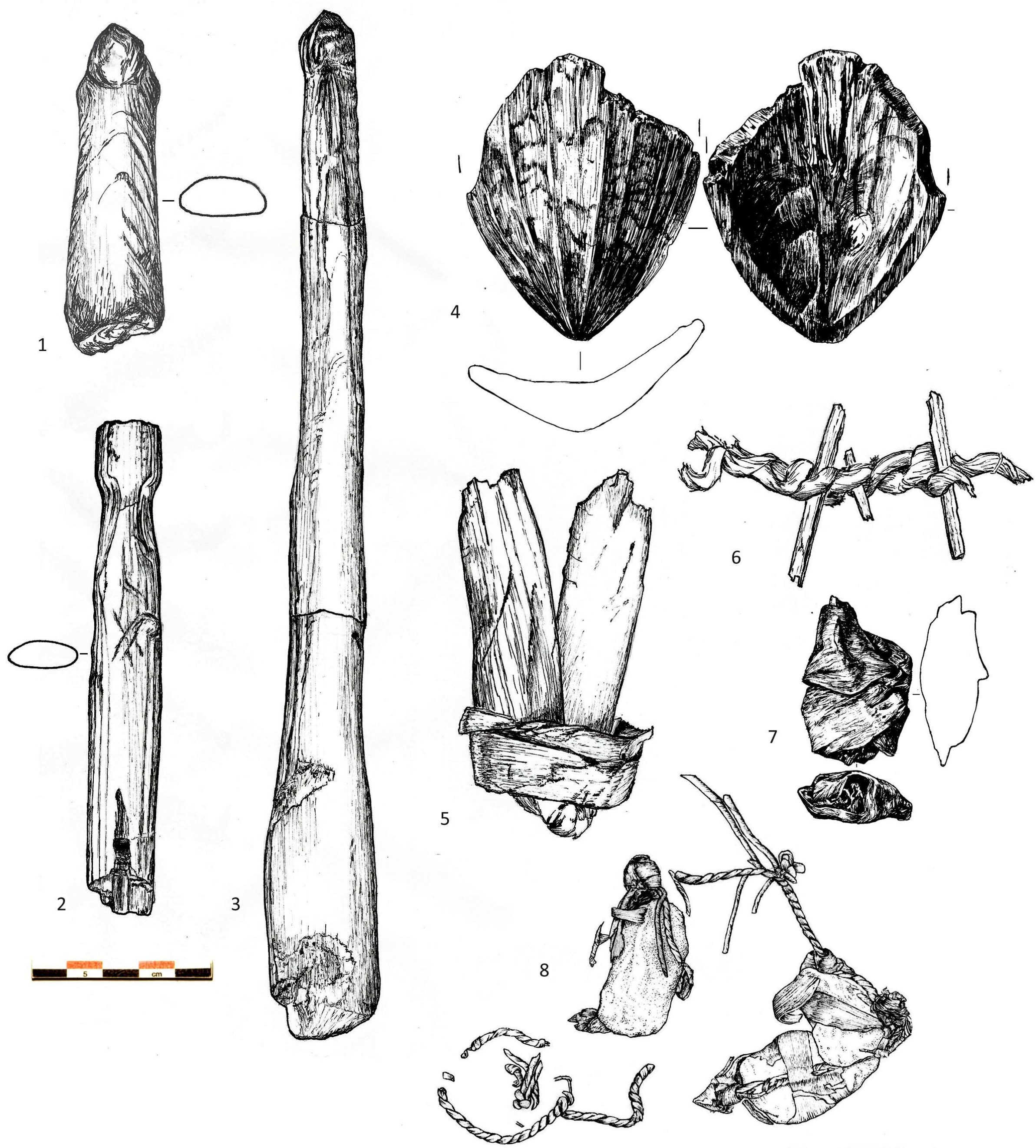

Figure 7: Serteya II. Parts of wooden bows (1–3); wooden vessel (4); lime bast knot (5); 6 – wooden splinters connected by ropes; 7 – fish sinkers. Serteya I: 8 – fish sinker.

Figure 8: Serteya I: fishing construction (1). Serteya II: part of a cloth (2). Underwater photo.

Broad-leaved species (ash, elm, oak, rare–pine, hazel, guilder, alder, juniper, lime, lime bast, birch bark, blueberry roots and sedge) were used for various tools and implements (Kolosova and Mazurkevich 1998) (Figure 7, Figure 8). Roots (black and brown colour), guilder berries (red) and their bark (blackish green) might have been used as colourants.

All of these wood species grew near the site, on the lake shores, slopes, and shores of lake basins. Changes in the ratio of broad-leaved and coniferous species for dwelling constructions and the disappearance of fir trees in the palynological spectrum by the end of the settlement's existence might testify active and strong anthropogenic influence. The only species remote from the site including pine, juniper and blueberry were spread 1 km to the north from the site or they grew on small felling sites near the settlement.

Pottery was made from hydromicaceous, smectite, and smectite-montmorillonite clays, according to petrographic analysis (Mazurkevich et al. 2014). Sediments in the vicinity of the site from the coastal part of the lake might have been used.

Flint and stone raw materials. A small number of nodules and nucleuses found at the site might provide evidence that the first stage of material treatment could have been conducted away from the site. Four types of raw materials were detected: two types of flints, mica slate, gaize, and erratics. Flint might have been brought from several outcrops in the Western Dvina River. These places are 10, 16, and 21 km away and more remote from the site. Part of the raw materials might have derived from tills of moraine plateaus located nearby. It is still unclear how flint raw materials were procured in the forests that covered these areas during the 3rd millennium BC, given that there were no stone pits or quarries found in this region. Stones might have been collected in gullies that cut morainic hills and in other open places.

A range of artefacts made from animal bones, teeth and antler were found on the site (Figure 9). Antlers, bones and teeth come exclusively from wild animals: elk (40 %), boar (8 %), beaver (6 %) and bird (1 %). Ulna, metacarpus, metatarsus, rudimentary metapodium, hyoid bone, teeth, and antler from elk were used, as well as beaver's lower jaw, boar's tusk and bird's humerus. Elk species supplied the main part of the raw materials devoted to bone tool production. Bone tools were used in many field activities, encompassing hunting, fishing, cooking, wood working, skin working, lithic production, etc. (Figure 10) (Maigrot 2014).

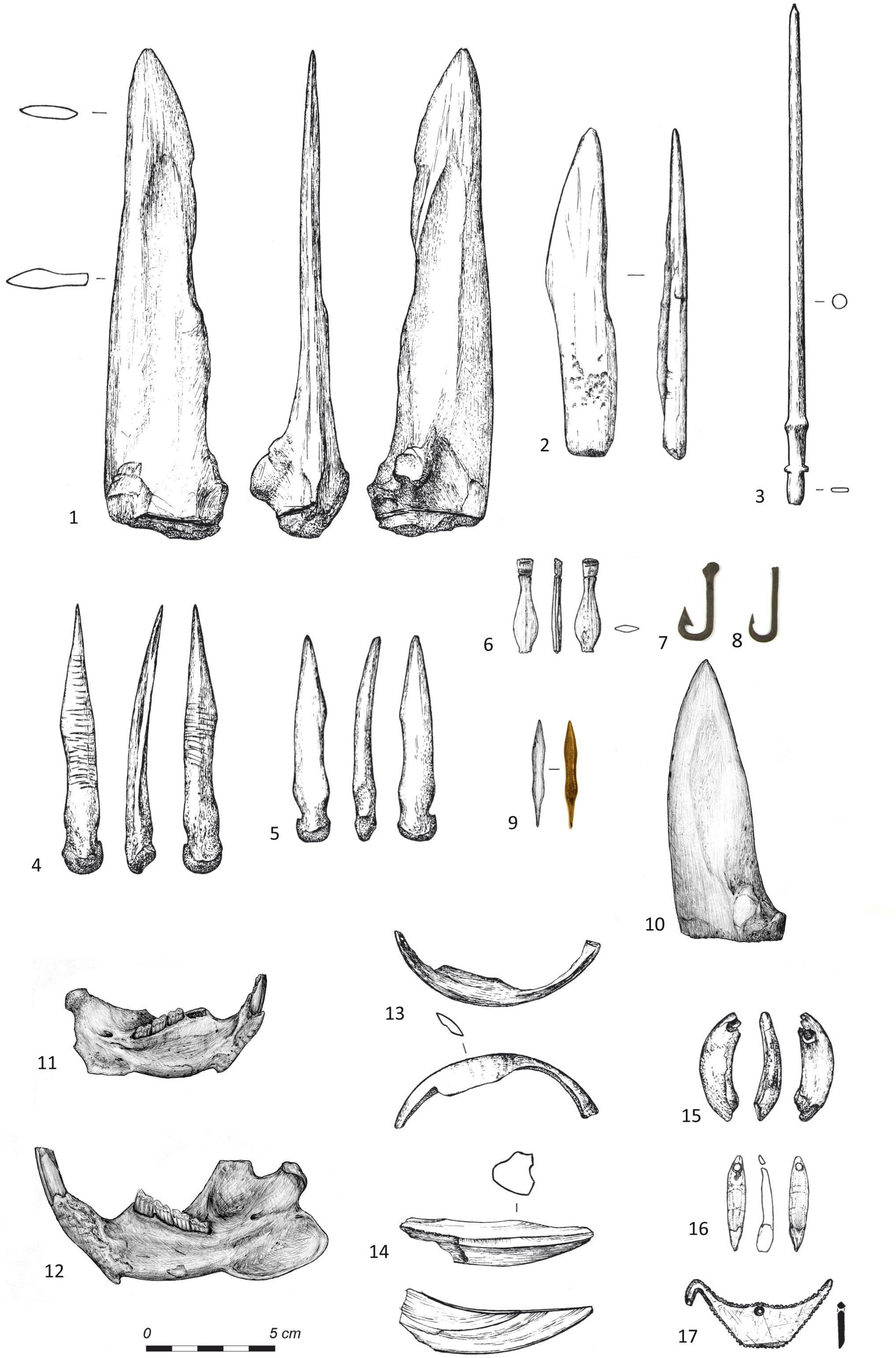

Figure 9: Bone tools from Serteya II: 1, 10 – knife on elk ulna; 2 – knife on elk metapodium; 3 – bone needle; 4–5 – points on elk's rudimentary metapodium; 6–8 – bone fishhook; 9 – arrowhead; 11–12 – scraper on beaver's jaw; 13–14 – scrapers on boar's tusk; 15–16 – pendants on elk's teeth; 17 – bone zoomorphic pendant.

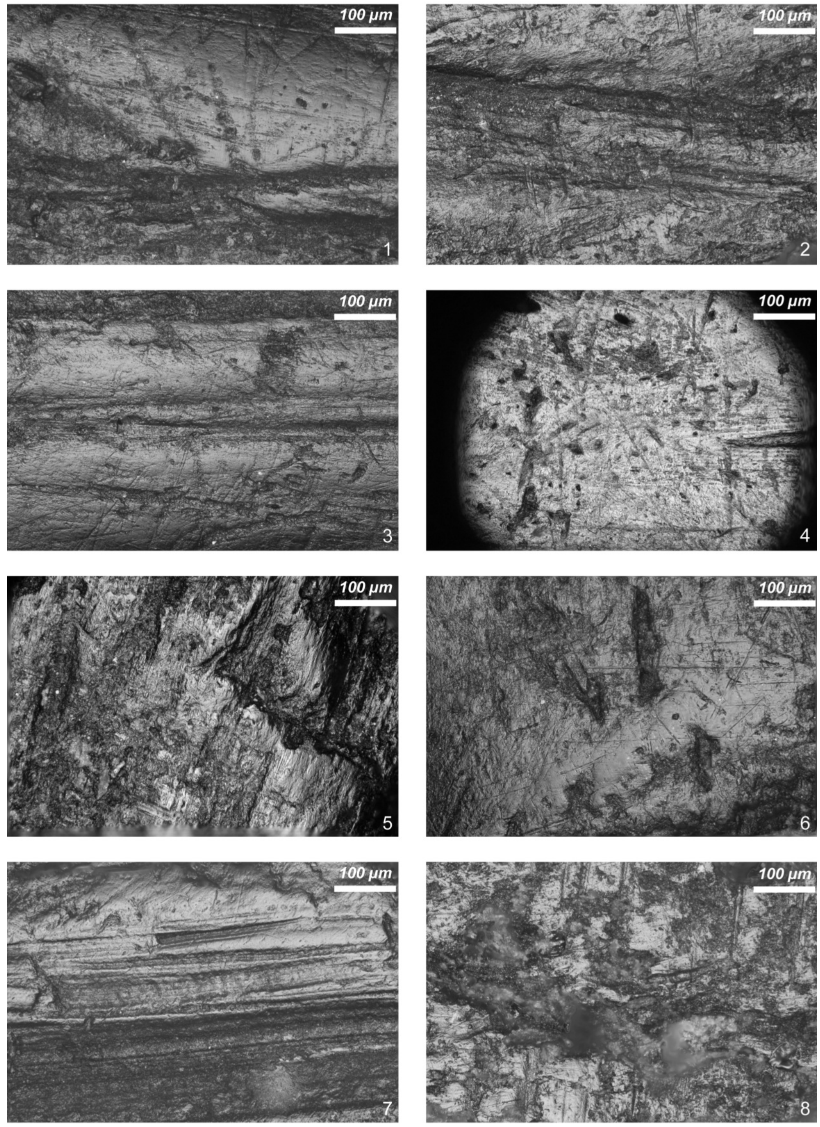

Figure 10: Wear traces on bone tools: 1 – perforating skin; 2 – basketry; 3 – hunting/shooting; 4 – fishing; 5 – retouching flint; 6 – timing/cutting wood; 7 – scraping wood; 8 – scaling fish. All photos were taken at 200x original magnification.

Conclusions

Resources that maintained the life of the pile-dwelling settlement throughout the whole year had to be used according to some strategy, which might have included various factors, including the accessibility of resources, some of them ceasing, their maintenance and renewal over time, the choice of the place for permanent and temporal settlements/sites according to some factors, etc. The seasonality and time period of site occupation were also important factors that conditioned the availability and number of different resources.

The accessibility and distance to different resources might have changed over time or depending on the season. Fir was used as a building material but disappeared after a while near the site, whereby the distance to this resource strongly increased. Activities in forests can also be traced through single finds of stone axes of the Middle–Late Neolithic. Seasonality and some strategy in different animals hunting (primarily the most meaty one, elk) can be also noted, based on faunal remains. Only parts of carcasses of large animals found on the site might provide evidence of remoteness of the area where the animals were caught. A small number of species recorded that could not supply the needs (in meat, raw materials for tools production, and skins) of inhabitants of this site during the whole period of its existence would provide evidence regarding the existence of other places where butchering was conducted. Single scrapers and arrowheads attributed to this time found in different parts of the valley might indicate temporal hunting and butchering sites or 'site satellites' of this permanent pile-dwelling settlement. Pottery similar to that one of the Serteya II site and remains of bones marking a butchering zone were found on the contemporaneous sites Serteya X and VIII. The remains of household constructions (without fire places) on the Serteya X and XIV sites might provide evidence regarding the existence of special storage and butchering places 500 m and about 4.5 km away from a basic settlement. They were located on the islands and shores of the lake.

Fishing and gathering products might have been the basis of a diet during spring and the beginning of autumn, whereas hunting took place during autumn–spring. Cattle-breeding and agriculture had not yet become the main source of food supply. Single bones of domesticated horse, cow, sheep and probably pig were found on the sites of this region (Sablin and Siromyatnikova 2009). Palynological data might indicate some agriculture activities (Arslanov et al. 2009; Dolukhanov et al. 2004).

Wood storage for building might have been the most effective during the winter period, due to the wood quality during this time and the ease of transportation. Wood for nets, ropes, textiles, baskets, and other basketry was most reasonable to be prepared during spring owing to the materials' quality.

Some of the resources were not available in the proximity of the site and specific campaigns had to be organised to the territories at least 10 km from the pile-dwelling settlement. 'Import' objects found on the site might have appeared here as a result of exchange with the territories up to 700 km away from the Upper Western Dvina basin, including amber raw material, some types of flint, and probably pottery.

All of these features are constituents of a very dynamic economic model that can be reconstructed for the community-inhabited pile-dwelling site Serteya II in the middle of the 3rd millennium BC. It broadens our understanding of multiple ways of hunter-gathering societies, including their economic and living choices.

Acknowledgements

The palaeoenvironmental research at the Serteya II site surroundings was financed by grants from the 'National Science Centre, Poland' based on decision No. 2017/25/B/HS3/00274. The participation of ZIN RAS (state assignment № AAAA-A17-117022810195-3) to this research is acknowledged. Field excavations and the exchange of knowledge was supported by the SNSF-funded NEENAWA project.

Archaeological research was supported by grant of Russian Science Foundation (project 'Lacustrine sites of the 4th-3rd mill BC - the origins and development of pile-dwelling settlements phenomenon in NW Russia' №19-78-00009). The archaeological mission 2NOR was supported by the French Ministry for Europe and Foreign Affairs.

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Geophysical prospection of submerged Neolithic settlements in Lake Sennitsa (NW Russia)

4

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The History of Discovery

The history of discovery of submerged archaeological sites on the bottom of Lake Sennitsa (NW Russia) (Figure 1) resembles the discovery of pile dwellings in Switzerland. In 1976, the water level was artificially reduced by 4 m. Upper parts of the wooden piles became visible and bottom sediments started decaying. Later, the water level was gradually increased, and currently it is about 2.5 m lower than previously. Local inhabitants began finding bone tools, clay vessels, flint, and wooden tools on the bottom of the lake and in their fish nets. Soon a small museum was opened in the local school of Dubokray village with finds from the lakes. History teacher I.A. Voschillo reported about these finds to A.M. Miklyaev, who organised investigations of these sites in 1979 by the north-western archaeological expedition of the State Hermitage museum (Miklyaev 1982, 1990).

Investigations started in 1979–1980 on the lake bottom near the Dubokray village on the Dubokray I' site, where the majority of finds were recorded. Low underwater visibility complicated underwater excavations and forced specific methods to be implemented. The whole surface of the site covered 20 x 20 m squares, facing cardinal points, where a topographical survey of the site and surroundings was conducted. These squares served as a basis for smaller square nets on the parts investigated for the more precise recording of materials. The pile-dwelling remains found in one of the squares comprised wooden piles, accumulations of wooden particles, organic objects, and clay vessels. It was noted that a cultural layer of the site located on the lake bottom at a depth of 70–120 cm started severely decomposing due to the freezing of the lake, wave motions, and anthropogenic influence. The cultural layer and materials were lifted to the surface by divers for further sieving (Miklyaev 1990).

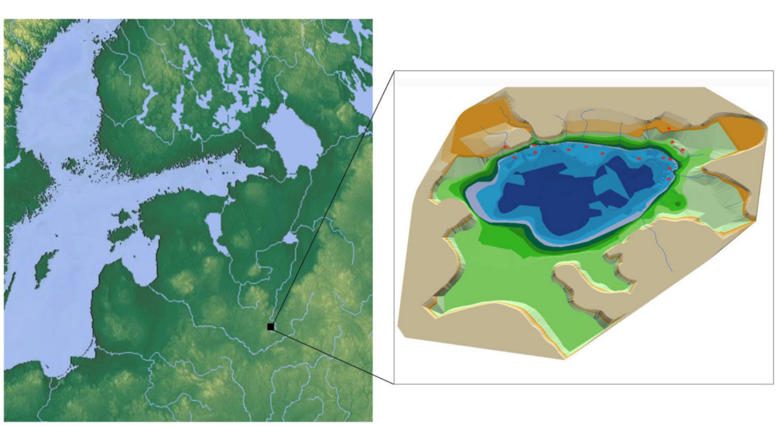

Figure 1: Sites distribution on Lake Sennitsa (NW Russia).

Mazurkevich, A.N., S. Lorenz, J. Fassbinder, R. Hensel, E.V. Dolbunova, E. Kazakov, E. Pavlovskaya (2020). 'Geophysical prospection of submerged Neolithic settlements in Lake Sennitsa (NW Russia)'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 37–58. DOI: 10.11588/propylaeum.714

In 1986, in a deeper part (depth 120–150 cm) on the north-eastern part of the lake, remains of an iron workshop — named Mosty — were found, dating to the middle of the 1st millennium BC. The 8 x 8 m log construction was divided inside by chambers of 4 x 4 m. Slag was found inside this construction and on its perimeter. First, the outer corners of the construction were marked by poles seen above water. Subsequently, logs were measured and put on the plan, and other elements of construction and zones of slag accumulation were recorded and marked by poles. Fragments of pottery were put on the plan and recorded according to the nearest pole (Miklyaev 1990).

Following successful excavations at the Mosty iron workshop, investigations of the cultural layer in the eastern part of the Dubokray V site began. Drillings into the bottom sediment on the slopes of a sandy hill began, at the edge of where the site was located to record the distribution of the cultural layer. This enabled making a description of bottom sediments and choosing the place with the most prominent cultural layer. 2 x 2 m squares were made and underwater excavations were conducted according to layers made by sieving and the recording of large pottery fragments. The bottom of the excavation was only 1 x 1 m because the ground was liquid and the walls of the trench were decomposing. The stratigraphy was revealed: at a depth of 1.1 m, a 55 cm thick layer of silt was found, which covered the cultural layer deposited in the peat layer with gyttja 28 cm thick, and beneath that sand and aleurite. Pottery fragments attributed to the second stage of Usviaty culture were collected at the low part of the silt layer and the upper part of peat layer. Pottery fragments of the first stage of Usviaty culture were found in the lower part of the peat with gyttja. Fragments attributed to Linear-band pottery (LBK) were recorded on the border of peat and gyttja (Mazurkevich and Dolbunova 2011; Miklyaev 1990).

An accumulation of Mesolithic materials and hearth 70 cm in diameter surrounded by stones was revealed on the Dubokray VI site located remotely from the Late Neolithic finds.

Results of Investigations of the 1980–90s

During this period, Dubokray I, V, VI, and iron workshop Mosty were investigated. The possibility of conducting underwater archaeological excavations in such difficult conditions was demonstrated. Rare finds from the Mesolithic era were made on the Dubokray VI site, comprising flint flake scrapers and tanged blade arrowheads.

Ceramic and flint materials of the early Neolithic era were found here, belonging to two cultural groups. Material from the Serteya archaeological culture dating from the 7th–6th millennium BC were found on modern lake shores near the Dubokray I and V sites. Pottery similar to LBK was found on the Dubokray V site, along with a few bones, antlers, flint tools, cylindrical amber pendants, and flutes (Figure 2). A few Neolithic era materials of Usviaty culture were found on the Dubokray I and V sites. Late Neolithic era materials of Zhizhitsa and North-Belorussian culture and typical Corded ware vessels were found at the Dubokray I–VI sites. A few fragments of vessels covered by geometrical incised lines similar to

Figure 2: Site Dubokray V: flutes.

those of agricultural communities of the Balkans dating to the beginning of the 3rd millennium BC were also found.

A large number of wooden particles and wooden logs were detected at the Dubokray I site under water, although wooden piles were not recorded. A trench was made on a peaty shore to trace a preserved cultural layer (Miklyaev 1982, 1990) (Figure 3). The remains of North-Belorussian cultural pile dwellings were found there, destroyed by great flooding that occurred at 3240±40 BP (Le-2839). This natural disaster had a macroregional character and it also destroyed the Serteya II and Naumovo sites in neighbouring microregions. Beneath the remains of the North-Belorussian cultural layer, a Late Neolithic cultural layer dated to 3870±40 BP (Le-2840) – 3860±40 BP (Le-2838) was found. This included pottery fragments, part of a ski made from elm and the fragment of a plough (Miklyaev 1990).

Figure 3: A.M. Miklyaev on the Dubokray I site.

A few fragments of vessels dating to the middle-second half of the 1st millennium AD were also found, showing the possibility of the existence here of early Middle Age settlements. This was evidenced by the finding of the Mosty iron workshop.

Analysis of the spatial distribution of the finds showed that surfaces covered by artefacts dated to different periods of time partly overlapped. Analysis of the topography, micro-relief, and stratigraphy of bottom sediments suggested the hypothesis that all sites uncovered were located inside a modern lake, which previously had several elevations among small lakes connected by a system of rivers. These elevations were separated from the bedrock shore by small rivers.

The main reason why these investigations were stopped was that the precise recording of all objects found, sieving, and other techniques could not be implemented due to the absence of necessary equipment. Remote technology was also useful to record all of the objects prior to excavation, and these technologies were not available in the early-1990s.

Renewal of Excavations in the 2010s: Aims and Results of Underwater Investigations

In the 2010s, investigations on Lake Sennitsa were renewed (Figure 4). As the result of these investigations, new sites were uncovered and the position of already-known sites was refined. It appeared to be clear that during later years organic sediments on the sites disappeared, whereby cultural layers were either destroyed due to natural processes or covered by a sandy layer, which deposited on top during the last decennia. The artefacts were found in new areas that were not investigated earlier given that there were no Neolithic materials. Artefacts were not found at the places of former excavations. These might have been destroyed or covered by recently-deposited sand.

Renewal of excavation work on Lake Sennitsa led to uncovering several new accumulations of stones on the Dubokray I site (Figure 5b). These

Figure 4: Topographical survey of Lake Sennitsa on the Dubokray I site (2012).

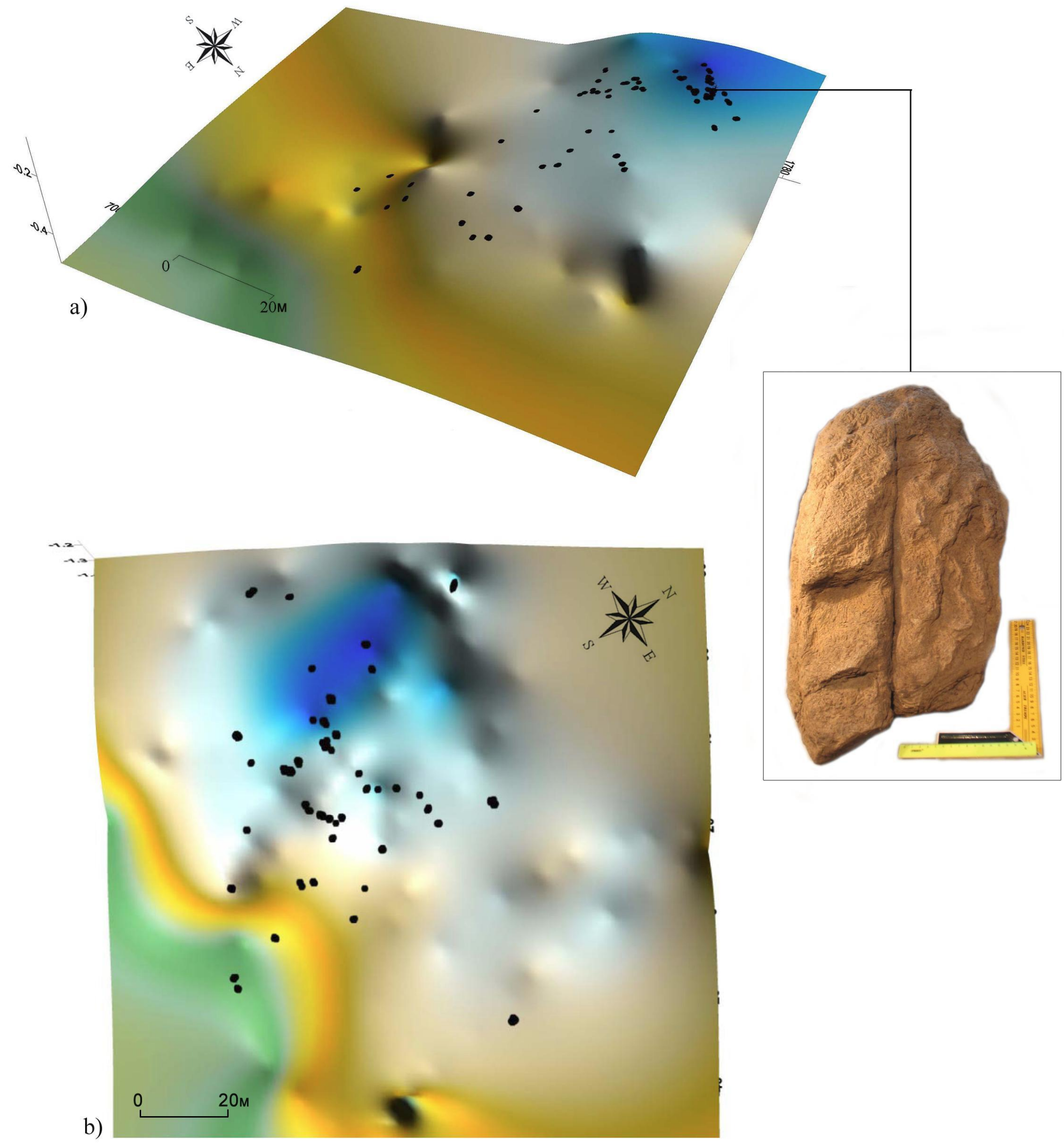

Figure 5: Plan of stones distribution on the Dubokray X (a) and I (b) site.

stones form a particular structure, organised as a circle in the central part with rays of stones coming from it. Excavations were made near the largest one, where smaller stones, an accumulation of charcoal, flint tools, and a stone adze were found. The charcoal was dated to 3690±50 BP (Le-9537). Furthermore, a large number of pottery fragments as well as complete vessels were found there. The material was concentrated in the central part of the site inside the construction on the elevation. We might suggest that this stone construction is located beyond the pile-dwelling settlement by comparing the plans of excavations of the 2010s and 1980s.

Another construction was found at the Dubokray X site (Figure 5a), comprising 83 stones 30–80 x 40–60 x 30–50 cm in size, rising 10–20 cm above the surface. The stones are organised into two parallel rows in the north-western area, the most elevated part of the site. Nearby single stones and accumulations of stones were recorded, organised in lines oriented north-east to south-west, and east to west. One of the stones 80 x 30 x 35 cm in size from the eastern row was lifted for examination. Oblong deepening with traces of pecking was recorded on it. A few artefacts were found on the site, concentrated in the pit, including a bone arrowhead, a stone polished axe, and eleven fragments of two or three clay vessels.

New sites were uncovered, named Dubokray VIII and IX, located in the northern part of Lake Sennitsa. Fragments similar to LBK pottery were found here, as well as Middle and Late Neolithic vessels of Zhizhitsa culture, Pit-comb ware, Globular Amphora culture, and Corded ware culture. A few bone tools and flint tools were also found (Figure 6). The remains of one wooden pile at the Dubokray IX site were dated to 4000±85 BP (Le-9536). Probably a pile-dwelling settlement existed here in the past, which can be evidenced by finds of vessels attributed to North-Belorussian and Zhizhitsa pile-dwelling cultures (Mazurkevich and Dolbunova 2011).

The results of underwater excavations led to the necessity to use non-destructive techniques for investigations on the shore and the bottom of the lake. The main aims — concentrating on the area around the Dubokray I site — included recording stone ('megalithic') constructions, finding buried objects, and finding the remains of wooden piles and constructions. An aerial survey was conducted on the shore line (Figure 7) and a relief map was reconstructed basing on this data (Figure 8). Geophysical prospections were conducted on various areas of the shore of Lake Sennitsa in the vicinity of the Dubokray I site, as well as on the lake bottom near the Dubokray IV and V site, whereby cross-sections were also made (Figure 9).

Figure 6: Pottery (1–2, 12-13), flint tools (7–10), bone arrowhead (3), slate axe (4), bone spatula (5), stone sinker (6), bone point (11) found at the Dubokray I (1, 7–8, 10), VIII (2, 9, 12–13), IX (5–6, 11), and X (3–4) site.

Figure 7: Aerial survey in the vicinity of the Dubokray I site.

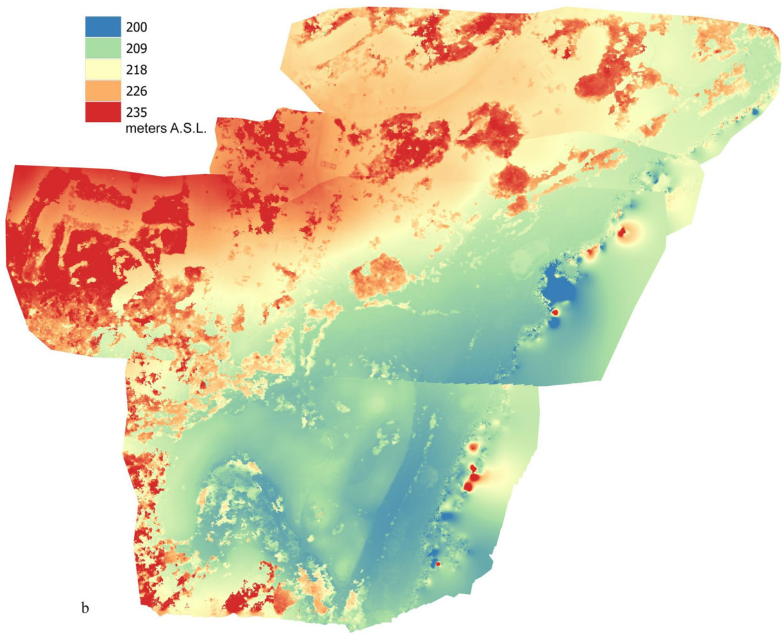

Figure 8: Relief reconstruction in the vicinity of the Dubokray I site.

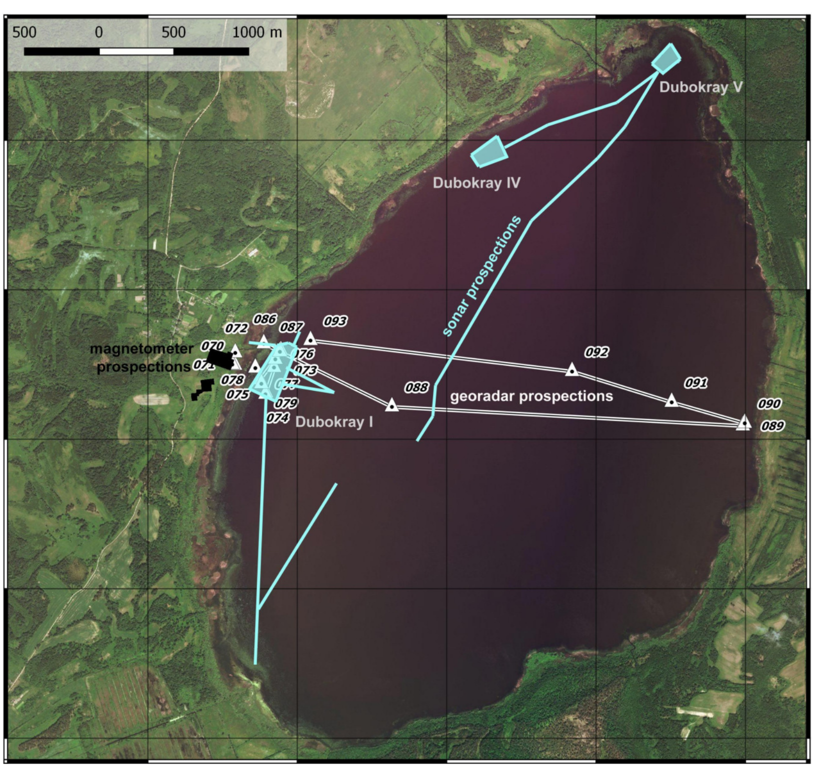

Figure 9: Map of Lake Sennitsa with indications of the places where geophysical prospections were made.

Geophysical Methods

For non-destructive and large-scale archaeological prospecting, geophysical science provides us with a multitude of different ground-based methods (Scollar et al. 1990). The most common among them are:

1. Magnetometer prospecting (passive method)
2. Radar prospecting (active method)
3. Resistivity prospecting (active method)
4. Sonar prospecting (active method)

Magnetometer prospecting is a 'passive' method, measuring a latent existing magnetic field, whereas the other methods are 'active' ones. These active methods — namely radar and resistivity prospecting — are regarded as suitable methods in the search of stone features, while the sonar method is among the most suitable method in the search of submerged features. They can be applied without being disturbed by modern technical constructions nearby, inside a modern city, or even inside a building. However, the application of these methods is more time-consuming and requires intensive and sophisticated data processing to display the results.

Several boundary conditions limit radar and resistivity prospecting methods. Saline and clayey soils, as well as swampland dramatically dampen the penetration of the radar waves. A rough and uneven topography makes a high-resolution radar survey utterly impossible. Resistivity prospecting is the most time-consuming prospecting method, and it is also limited by the conductivity differences of the mostly wet and muddy topsoil layers at the Dubokray I site.

Magnetometer prospection

The Dubokray I site is situated on the coastline of Lake Sennitsa is partly covered by water, and it extends up the slopes of slightly elevated hills. Therefore, on the swampy and wet grassland of the site, magnetometer

Figure 10: Magnetometer prospecting in action with the handheld duo-sensor cesium magnetometer at Dubokray (Photo: Dima Michaylov).

prospection remains the best suitable method for large-scale and high-resolution prospection (Aspinall et al. 2008; Fassbinder 2017). However, the muddy terrain conditions pose a major challenge. The area is partly interspersed with pools and small ponds up to 50 cm in depth and several metres wide. These conditions require a magnetometer equipment and configuration that is rather tolerant of tilting of the instruments, as well as a variation in the exact distance from the ground. For our purpose, in order to reach the highest possible sensitivity combined with a maximum speed of prospection we chose a caesium total field magnetometer (Scintrex SM4-G Special). We implemented the instrument in the so-called 'duo-sensor' configuration. Using this configuration, we mounted the probes on a wooden frame and carried them in a zigzag pattern c. 30 +/- 10 cm above the ground (Figure 10). The profiles of our 40m x 40m grid were oriented east to west to minimise technical disturbance and interactions of the magnetometer probes with the electronic parts and the batteries of the device. The instrument allows us to measure the Earth's total magnetic field by a sensitivity of ±10.0 picoTesla with a sampling rate of ten measurements per second. For comparison, the Earth's magnetic field in Dubokray I site varied in the range of 51,730 ±10 nT in May 2013 and 51,860 ±20.0 nT in May 2016.

The sampling frequency of the magnetometer (ten readings per second) allowed the survey of a 40 m profile in less than 30 seconds, maintaining the spatial resolution of a data sampling (ten measurements per second) of approximately 10–15 cm by normal walking speed. Every 5 m, in parallel to the magnetic data, a manual switch set a marker. This helped us to perform the best and most exact interpolation of data during the subsequent laboratory processing work. We removed the slight linear changes in the daily variation of the geomagnetic field by a reduction filter and calculated the mean value of the 40 m profile. Additionally, we calculated the mean value of all data of the 40 × 40 m grid and subtracted this value from the survey data. Hereby, we assumed that the variation of the Earth's magnetic field during the measurement of one 40 m profile followed a linear increase or decrease in the intensity of the Earth's magnetic field. Thus, it was possible to eliminate this variation for each traverse line by a reduction to the mean line value. This procedure filtered apparent linear structures parallel to the profile. Alternatively, in magnetically quiet areas, it is also useful to calculate the mean value of the whole 40 × 40 m grid and use this value for further data processing as described above. In order to create discrete field values, we used a resampling program, setting the data to a sampling interval of 25 × 25 cm. Accordingly, we obtained the intensity difference between the measurement of both the magnetometer probes and the theoretically-calculated mean value of the Earth's magnetic field. The data (displayed as a grey shade image) reflects the apparent magnetic anomaly caused by the magnetic properties of the archaeological structure, the soil magnetism, and the geology. In order cancel the natural micro-pulsations of the Earth's magnetic field, we applied a band pass filter in the hardware of the magnetometer processor. Usually more than 98 per cent of the magnetometer data in a 40 m grid on archaeological sites varies within the range of ± 10 nT from the corrected mean value of the geomagnetic field. We ascribe the stronger anomalies to burned structures, lightning strikes, or pieces of iron containing slag or iron rubbish. In-situ burning, pieces of iron, and traces of lightning strikes are easily distinguishable not only by their different direction of magnetic dipole anomalies, but also by their high intensities (> ± 50 nT).

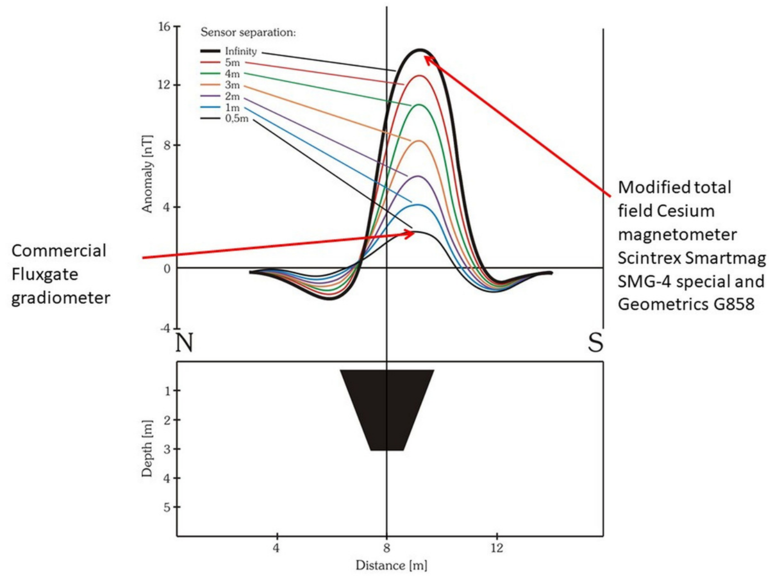

Figure 11: Dependence of the intensity of a magnetic anomaly of a typical prehistoric feature such like a ditch, on the sensor separation (gradient) of a commercial fluxgate gradiometer (50–65 cm gradient) and a total field cesium magnetometer with a virtual gradient of > 5 m.

The implementation of the optical pumped cesium magnetometer Smartmag SM4G-Special in the so-called duo-sensor configuration allowed setting the reference value — e.g. the virtual gradient of the Earth's magnetic field — to infinity, and measured magnetic anomalies with full intensity (Figure 11). The major advantage of this configuration is rather obvious: the resulting data and the grey shade image delivers more information about the site, including from the deeper parts of the archaeological structures. The application of a high-pass filter to the data allowed us to discriminate geological features (such as paleo-canals) from deeper soil layers, as well as extensive distributions of highly magnetic ash layers from discrete and detailed archaeological features in the top soil.

The instrument itself allows us to measure the Earth's total magnetic field by an intrinsic sensitivity of ±10.0 picoTesla with a sampling rate of ten measurements per second. For comparison, the daily fluctuations of the Earth's magnetic field in Dubokray (5/2016) varied within the range of 51,850 ±20.0 nT. The data were stored as binary files on the read-out unit, then downloaded to a Panasonic Toughbook and unpacked to ASCII data. For image processing and further treatment of the data (resampling), we applied special self-made software, the program Geoplot (Fa. Geoscan Ltd. UK) and Surfer (Golden Software, USA). The visualisation as a greyscale image (magnetogram) allowed us to trace even the smallest anomalies provoked by the remains of single posts and palisades beneath the surface. The application of a high-pass filter removed the deeper and mainly geological features and gave us supplemental information on the type of the anomalies. We displayed the later results by a second magnetogram image.

For the integrated interpretation, we classified the findings by:

1. the shape of the feature (based on archaeological background knowledge);
2. the intensity of the magnetic anomaly;
3. the direction and intensity of the remnant magnetisation; and
4. the induced magnetisation (volume magnetic susceptibility).

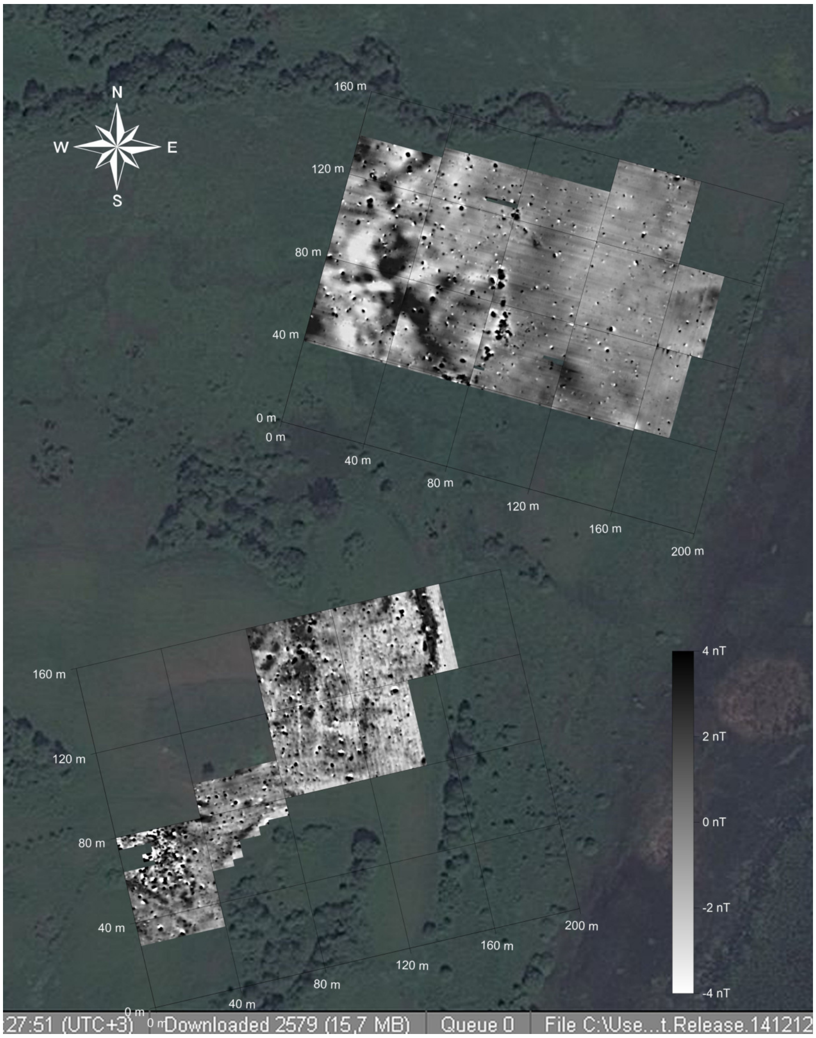

Figure 12: Dubokray. Satellite image overlaid by the magnetogram images from 2013 and 2016 of the site as a grey shade plot. Cesium-Smartmag SM4G-special-magnetometer, duo-sensor configuration, sensitivity ±10 pT, sampling interval 12,5 x 50 cm interpolated to 25 x25 cm in 40 m grid. Total field values were reduced to the mean value of a 40 m square and partly fused by a high-pass filter magnetogram, dynamics ±4 Nanotesla from black to white.

Points 2–4 are justified by the theoretical background of applied geophysics and the knowledge of rock magnetism and supplementary susceptibility measurements (Dunlop and Özdemir 1997; Fassbinder 2015; Jordanova 2017).

The outer conditions at the site were particularly difficult due to small bushes, water ponds, and swampy grassland, but no other limitations. We staked out a 40 x 40 m grid in a north-south orientation and measured the location of the stakes separately by GPS. We marked the direction of profiles by plastic ropes at a distance of 2 m to guarantee an exact sampling density of 12.5 x 50 cm (Figure 10).

Results of Magnetometer Prospection at Dubokray I

The northern part of the survey area forms a swamped area, partly covered by water of Lake Sennitsa. In the summer, large parts of the area are inaccessible due to the high reeds and grass. The southern area is slightly elevated, and it has probably never been covered by water in the last 8,000 years (see Figure 12). Here, on uneven terrain, we found traces

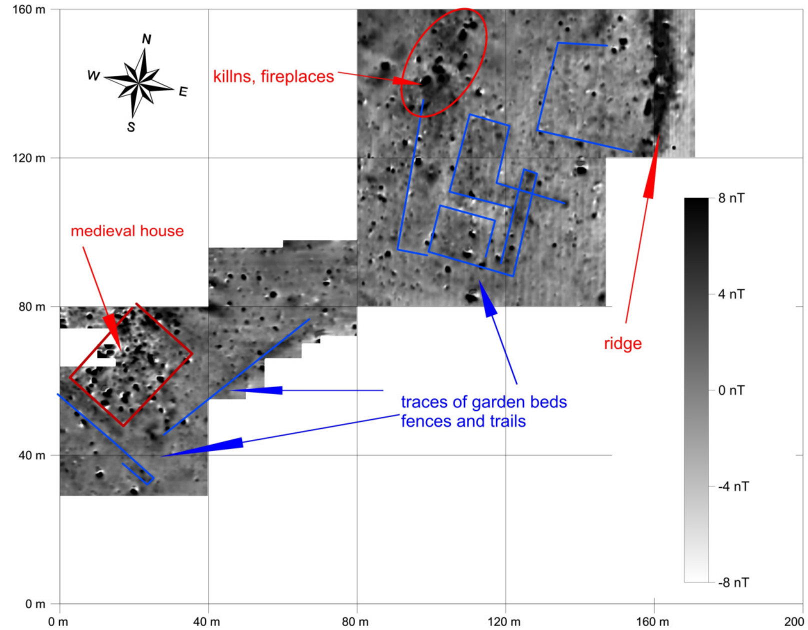

Figure 13: Dubokray. Magnetogram image from the southern part of the site as a grey shade plot. Cesium-Smartmag SM4G-special-magnetometer, duo-sensor configuration, sensitivity ±10 pT, sampling interval 12,5 x 50 cm interpolated to 25 x 25 cm in 40 m grid, total Earth's magnetic field in Dubokray: 51 860 ±20 Nanotesla (Mai 2016). To highlight the features, we overlaid total magnetic field data by a high-pass-filter image (a). Magnetometer image with interpretation (b).

of an old farmstead and the ruins of a monastery from the medieval period. Parts of the area seemed to serve as gardens or fields of vegetables. Therefore, the two areas strongly differ with respect to their geochemical conditions and their soil magnetic properties.

The magnetometer data of the southern area was visualised as a grey shade plot in 256 greyscales with dynamics of ± 1–4 nT from white to black (Figure 13). The measurements revealed features mostly from the medieval period. We detected a rectangular area that is very probably the remains of a house. Moreover, there are rectangular aligned traces of palisades or wooden fences that enclose areas of highly magnetic soil, which could be the remains of garden beds and small plots of land subdivided by trails. The beds are visible by a slightly darker anomaly, while the trails show up as white traces.

Besides these linear and rectangular features that very probably belong to the medieval period, we traced a multitude of pits and postholes, as well as fireplaces or kilns that cannot easily be dated by our magnetometer survey. However, on the surface, we also found pottery fragments from the Neolithic period, indicating that at least some of the pits and undefined features could be traces from a Neolithic settlement.

The northern area of the survey site is situated on low-moor soil. The anomalies that we traced on this swampy area considerably differ from those in the southern part not only by their intensity (Figure 14). Nevertheless, we are able to suggest a comprehensive interpretation of the place. The site is dominated by ancient water channels and paleo channels meandering through the survey area. In between the paleo channels (slightly white), we see zones of magnetic enrichments (in the magnetogram image, they appear dark/grey) and highly magnetic features that could be hearths, fireplaces, or the ground floors of Neolithic houses. Some of these anomalies form a group (inside the ellipse), while others are found more erratically in the western part of the area (Figure 14, Figure 15). The whole area shows traces of single posts, some of them ar-

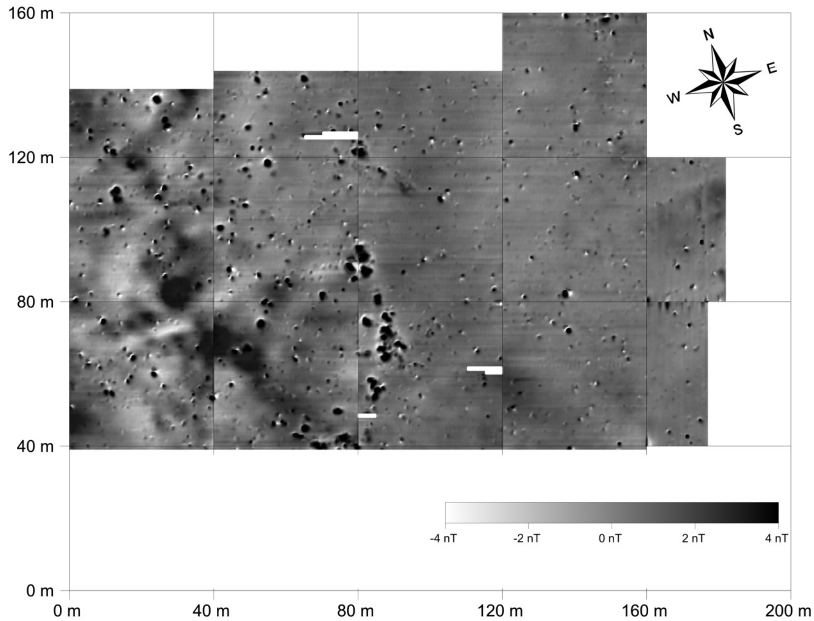

Figure 14: Dubokray. Magnetogram image from the northern part of the site as a grey shade plot. Cesium-Smartmag SM4G-special-magnetometer, duo-sensor configuration, sensitivity ±10 pT, sampling interval 12.5 x 50 cm interpolated to 25 x 25 cm in 40 m grid total Earth's magnetic field in Dubokray: 51 730 ±10 Nanotesla (Mai 2013). To highlight the features, we overlaid total magnetic field data by a high-pass-filter image (a).

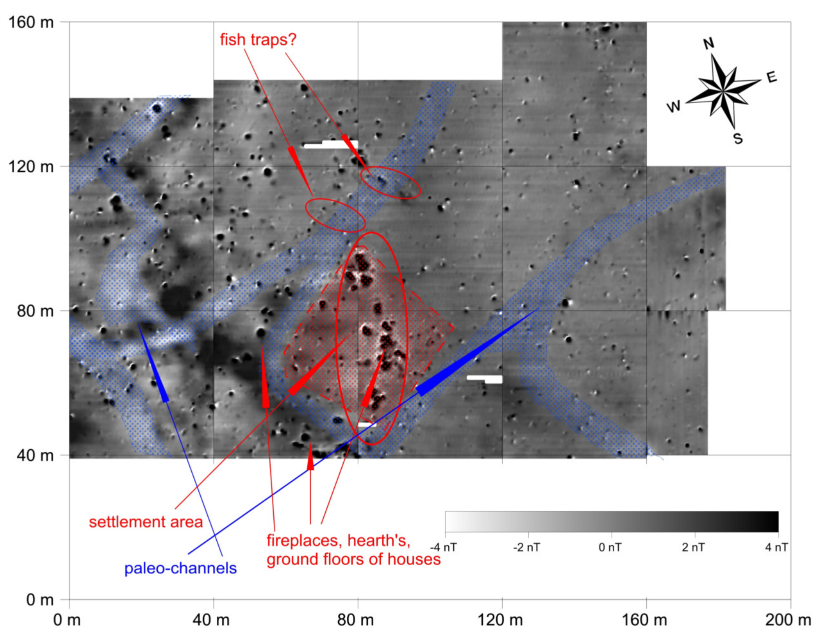

Figure 15: Magnetometer image with interpretation.

ranged in a row of three or four posts. Some rows of posts are arranged inside the paleo-channel, indicating traces and remains of fish traps.

The interpretation that some areas are paleo channels due to the depletion of magnetic minerals while other areas are the fireplaces and ground floors of houses due to high-magnetic ashes, and the general enrichment of magnetic minerals around the ancient settlements is quite comprehensive and plausible. However, the occurrence of distinct positive magnetic anomalies of wooden posts adjacent to the low-moor soils requires further rechecking and verification by mineral magnetic measurements and soil samples (Fassbinder 2015; Fassbinder et al. 1990).

Figure 16: Side sonar processing.

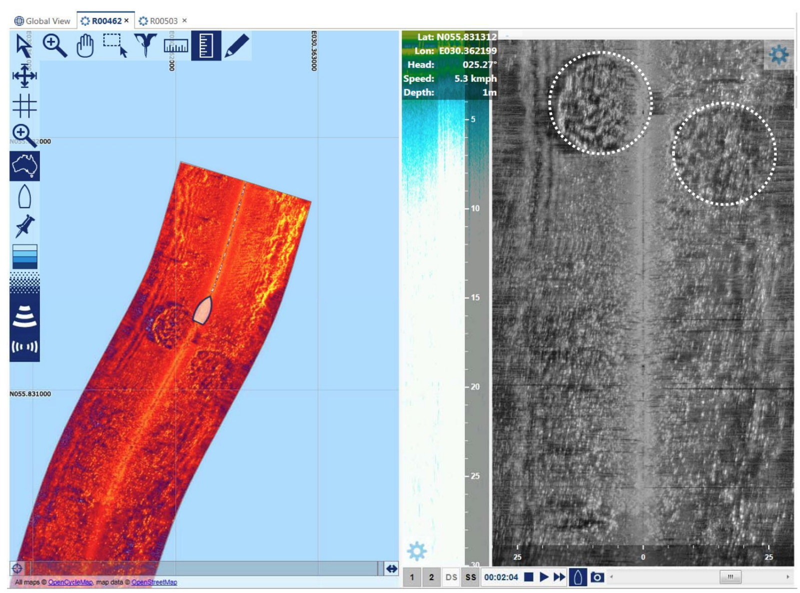

Figure 17: Sonar survey. Stone structures with echo quality and water depth. Red colour indicates a hard lake bottom with good echoes and diminished water depth.

Sonar prospection

Supplemental archaeological underwater survey investigations of the bottom of modern Lake Sennitsa were conducted (Figure 16). Three sites in the littoral fringe were investigated by dense side scan sonar tracking with varying frequencies. The Hummingbird 1198 SI Combo sonar device using down- and side-beam frequencies of 83/200 kHz was used. The sonar mapping revealed details in the lake bottom morphology, which was recently enveloped by soft sediments. It also revealed a range of different anomalies, interpreted to be the remains of different wooden and stone constructions (Figure 17, Figure 18, Figure 19). The length of the shadow indicated a >0.4 m elevated structure with ~12 m diameter. The structure was very sharply defined by a hard and plateau-like surface with

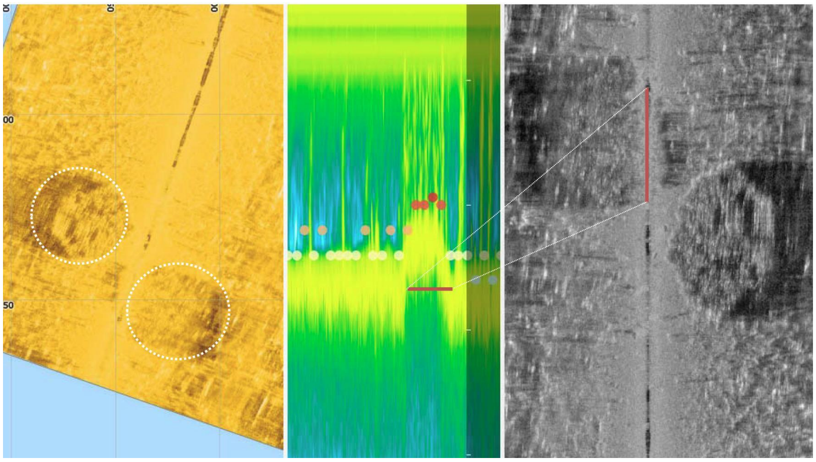

Figure 18: Sonar survey. Stone structures with echo quality and water depth.

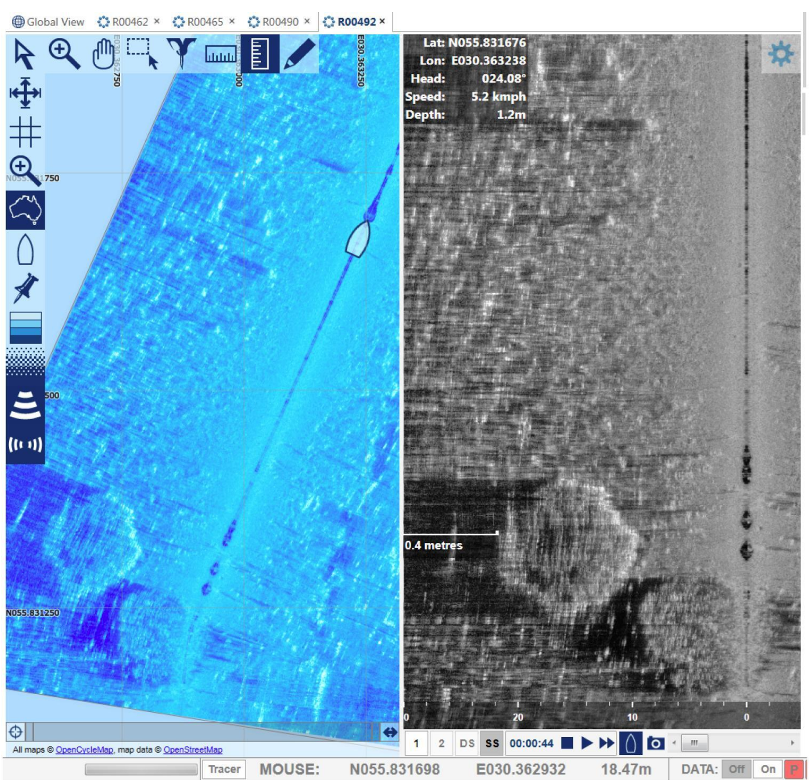

Figure 19: Sonar survey. Stone structures with echo quality and water depth. The length of the shadow indicates a >0.4 m elevated structure with approximately 12 m diameter.

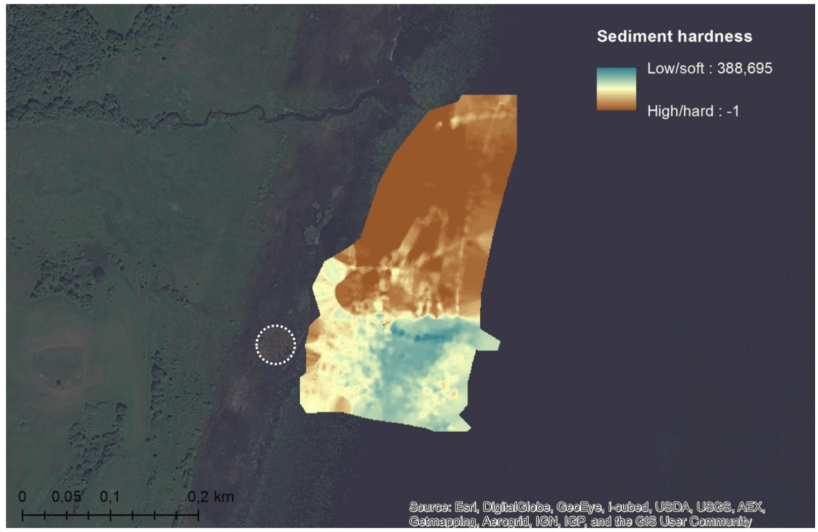

Figure 20: Sediment hardness in a littoral zone.

a ring wall. Further underwater surveys conducted here confirmed this interpretation.

The littoral zone can be divided into a northern hard bottom part and a southern muddy part (Figure 20). The location of the former river bed or anthropogenic structure (ditch?) can be suggested. Some possible circular structures 11–20 m diameter can be seen on the modern muddy shore of the river.

Georadar prospection

A ground-penetrating radar (GPR) survey was conducted in the water area and the shore of Lake Sennitsa (Figure 21). The 'OKO-2' GPR with an antenna with a centre frequency of 150 MHz (LOGIS-GEOTECH company)

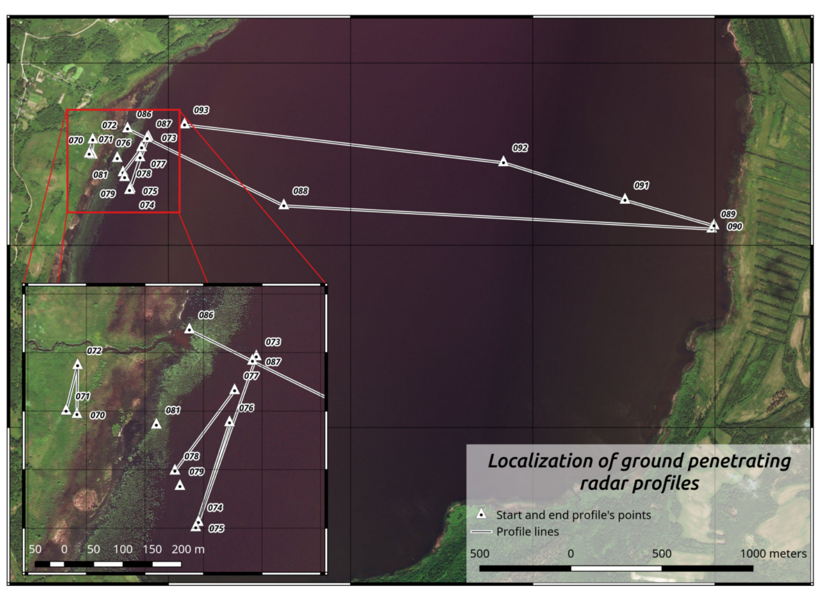

Figure 21: Localisation of GPR profiles. Picture made by E. Kazakov.

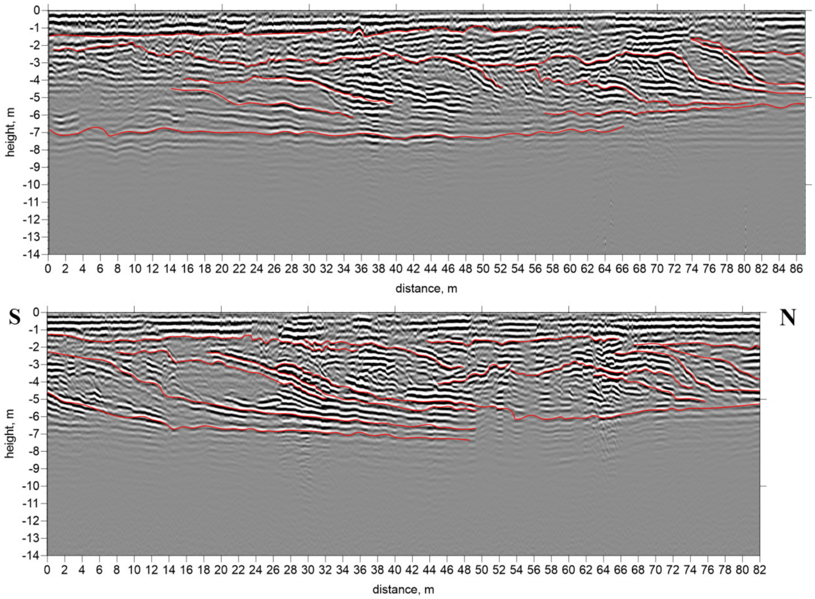

Figure 22: Radargrams from Lake Sennitsa, from point 070 to 072 (upper) and from point 071 to 072 (lower).

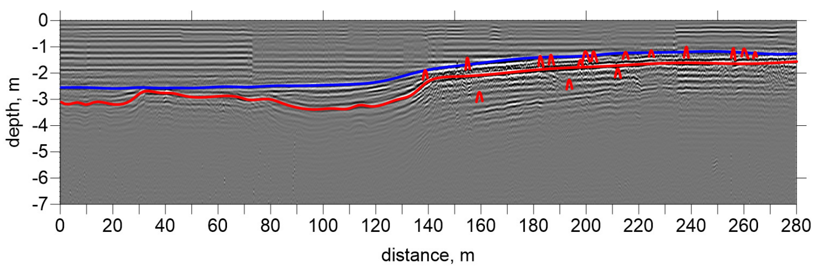

Figure 23: Radargram from Lake Sennitsa, from point 081 to 082.

was used. This GPR survey on the shore of the lake showed a series of clinoforms on the radargrams, which might to be alluvial origin (Figure 22). Their orientation indicates the general direction of the flow from south to north, although it might have also been in the west to east direction. The thickness of the river deposits is up to 6 m. The composition is predominantly sandy with interlayers of silty-clay material. For more accurate determination, drilling data should be obtained. On the lake surface, the GPR survey was conducted using a boat. Near the shore, in the area where the largest number of finds were discovered as a result of underwater archaeological work, six profiles from 170 to 310 m long were laid. Due to the problems with the GPS receiver, not all of them are precisely tied to the terrain, and only three profiles are rendered on the map (Figure 21, Figure 23). The data obtained were largely noisy, whereby the boundary of the bottom of the lake (shown in blue) and the bottom of the upper layer of bottom sediments (shown in red) are distinguished. On all radargrams in the area near the coast, there are many hyperbolas that indicate the presence of local diffracting objects. The antenna gives a resolution of objects to 0.35 m, whereby it is not possible to detect smaller piles. However, it might be groups of them, or other objects. In Figure 24, detected objects on the profiles are shown with red dots.

Two GPR profiles were also laid across the lake in the west to east direction (Figure 21). Hyperbolas were only observed on the western shore of the lake, in the same area where they were found on the rest of the profiles, while in the central and eastern parts of the lake there were none.

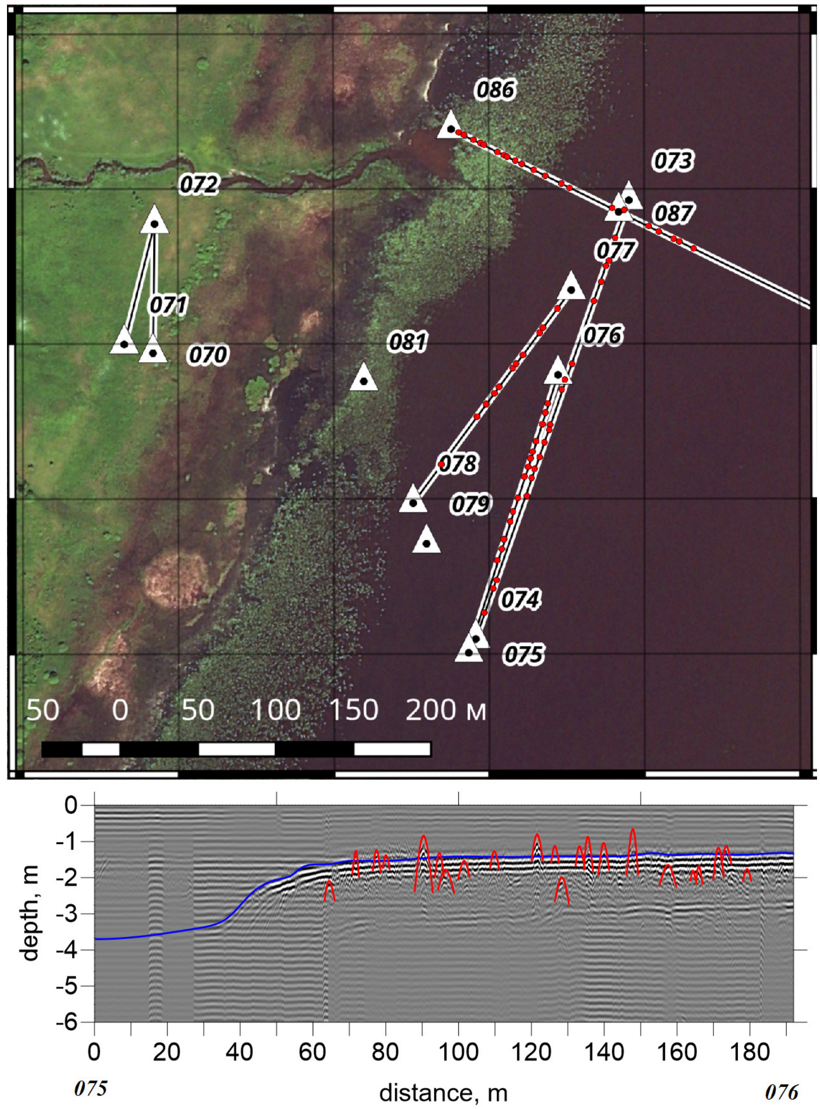

Figure 24: Detected objects at the bottom of the lake (red dots on the map) and radargram from point 075 to 076.

Conclusion

A variety of lacustrine sites from Mesolithic to Middle Ages were found on the bottom and shore of Lake Sennitsa. They were located along the shorelines of small lake basins and rivers distributed on the recent lake bottom. Neolithic sites comprise the first settlements of LBK communities in this region, comprising prehistoric pile dwellings, and the eastern-most megalithic construction of the 3rd millennium BC known in Europe thus far.

During the last twenty years, the cultural layer on the bottom of the lake has been either destroyed due to lake-level drawdown or buried under modern lake sediments. In order to find further traces of archaeological constructions and cultural layers, a range of remote sensing and geophysical methods — both underwater and on the peat-bog shore — were applied and the first results were gained. These prospections allowed reconstructing detailed paleorelief maps, the precise distribution of ancient stones and wooden constructions on the sites, and offered suggestions of places for further excavations. Moreover, this provided a comprehensive approach to the site. Aerial surveys show clear traces of roundish objects, which were also traced by sonar prospections of the littoral part of the lake. Some of them might represent stone platforms up to 15–22 m in diameter. Mapping revealed details in lake bottom morphology — which was recently enveloped by soft sediments — and revealed a range of different anomalies, interpreted to be the remains of different wooden and stone constructions. This was confirmed by underwater archaeological prospections showing the accumulations of stones and the concentration on these exact places of vegetation, which might be the marker of organic-rich areas located here. For the first time, a new type of previously-unrevealed stone construction was found, round stone platforms, most probably attributed to Neolithic times.

Magnetic prospections made on a shore muddy area of the Dubokray I site revealed a series of ancient water channels and paleo channels meandering through the survey area. In between the paleo channels, some features can be identified and interpreted as hearths, fireplaces or ground floors of Neolithic houses. The whole area shows traces of single posts or rows of posts. Previous excavations had already revealed remains of pile dwellings, including pottery, wooden ski and other artefacts, and remains of destroyed constructions found in the trenches made on a peat-bog shore part.

These results show strong potential for future investigations on these sites including its underwater and shore parts.

Acknowledgements

Archaeological research was supported by grant of Russian Science Foundation (project 'Lacustrine sites of the 4th-3rd mill BC - the origins and development of pile-dwelling settlements phenomenon in NW Russia' №19-78-00009).

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Pile dwellers in the Sukhona basin? Wooden structures of the 4th and 3rd millennium cal BC at Veksa, Northern Russia

5

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Veksa — a diachronic reference site of the NE European forest zone

The multi-period site of Veksa is a key location with regard to the cultural development of Northeastern Europe. With its extensive package of archaeological remains up to three meters thick and the good preservation of organic material especially in the lower horizons, the site enables a reference chronology to be developed for prehistoric cultures and the history of environment in north-eastern Europe that covers a time span of more than eight millennia. The unique sequence of cultural layers comprises all periods from the Early Neolithic (Ceramic Mesolithic in European terminology) of the 6th mill. cal BC through to the Medieval Period, including an extensive concentration of wooden piles and structures of the Late Neolithic (Nedomolkina 2000). Such a comprehensive series of archaeological remains encompassing a similarly large portion of the Holocene almost without any gaps is a very rare occurrence in the vast region between the Baltic and the Urals, best comparable, perhaps, to the pivotal stratified site of Rakushchechnyj Yar, southwards in the Lower Don region of southern Russia (Mazurkevich and Dolbunova 2015). Veksa represents a crucial monument in the European forest zone, and new research has now further developed its great potential for the diachronic assessment of human-environment interactions and, connected to this, of economic developments including the introduction of agriculture.

Located in the upper Sukhona basin ca. 20 km east of the provincial capital Vologda and ca. 400 km north of Moscow, Veksa is situated on an important river confluence of the Vologda and Sukhona rivers and at the same time in the vicinity of the European watershed (Figure 1, Figure 2). This favourable location was probably one of the reasons why the place had been a focal point for settlement ever since the Neolithic period. Archaeological remains extend along the left bank of River Vologda on both sides of the small tributary Veksa. The area west of the Veksa mouth is called Veksa 1, while the stretch to the east is named Veksa 3 (Figure 3). The cultural layers lie within floodplain sediments, indicating millennia of seasonal riverside settlement. The Stone Age remains are especially well preserved due to partial water-logging, they include the abovementioned concentrations of wooden stakes, piles, and fishing baskets of the Late Stone Age directly at the river bank (Figure 4). Today this unique archaeological monument is endangered due to the ongoing erosion of the river bank, and modern investigations aim to document the wealth of culture-historical and environmental information provided by this site.

Archaeological works at Veksa started in 1981. Under the direction of Nadezhda G. Nedomolkina, archaeologist at the Vologda State Museum-Preserve, an increasing understanding of the culture-historical de-

Piezonka, H., N. Nedomolkina, V. Elberfeld, K.-U. Heußner, W. Kirleis, S. Lorenz, M. Wieckowska-Lüth (2020). 'Pile dwellers in the Sukhona basin? Wooden structures of the 4th and 3rd millennium cal BC at Veksa, Northern Russia'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 59–93. DOI: 10.11588/propylaeum.714

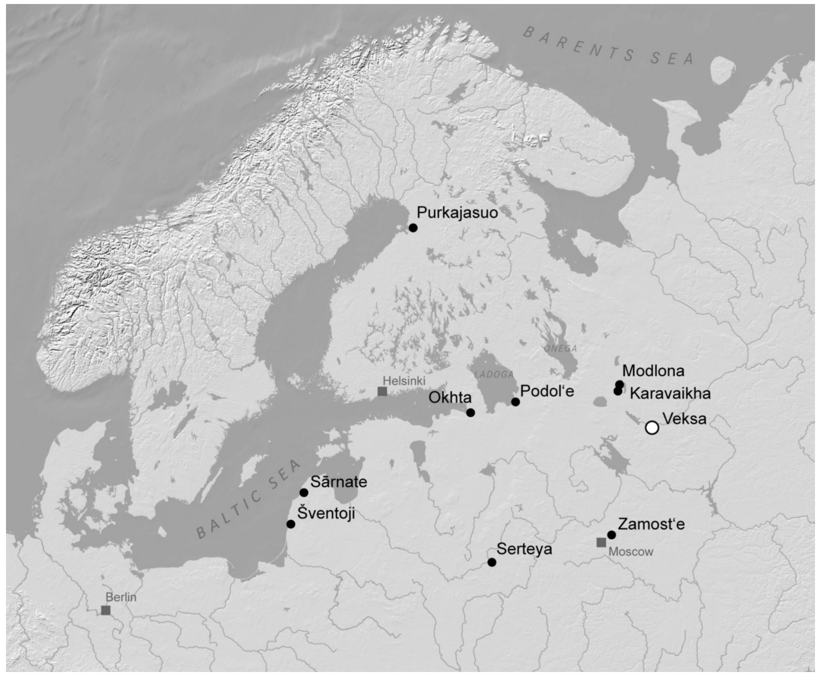

Figure 1: Veksa in NE Europe and other sites mentioned in the text. Illustration Henny Piezonka.

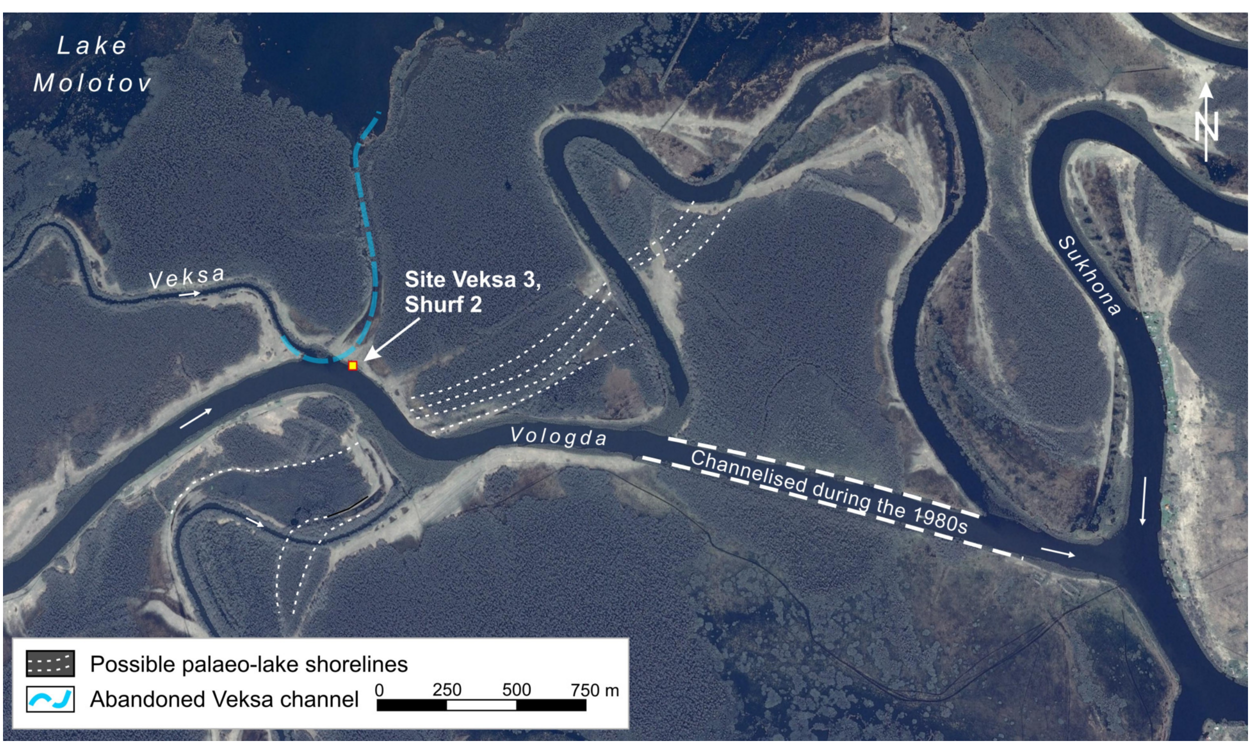

Figure 2: Satellite image of the investigation area with River Vologda and River Sukhona junction, the confluence of the small tributary Veksa as well as the southern fringe of lake Molotov. The image shows the hydrographic situation during high water levels in spring time. Illustration Sebastian Lorenz (based on Google Earth image).

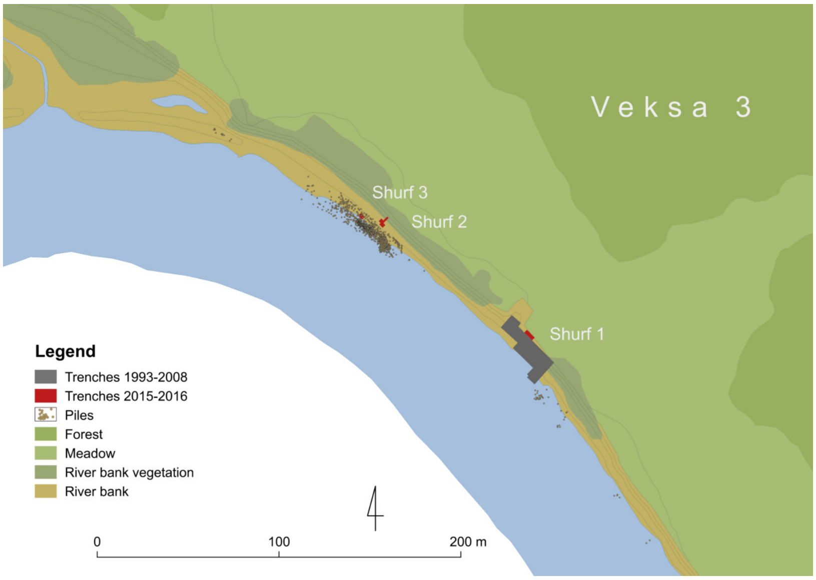

Figure 3: Veksa 3. Pile concentrations at the northern bank of Vologda River and excavation trenches. Illustration Christoph Engel.

Figure 4: Veksa 3. Main pile concentration at low water in September 2011, seen from the southeast. Photo Sebastian Lorenz.

velopments in the region has been worked out (Nedomolkina 2000; Недомолкина 2004). Since 1993, seven areas of various sizes were excavated along the river bank of Veska 1 and one area at Veksa 3, focusing on areas which were especially severely damaged by erosion. These works led to a detailed picture of the variation of the archaeological sequence and the respective cultural complexes preserved in various parts of the river bank. In years with low water levels, a concentration of well-preserved wooden piles was noted in the lower part of the bank of the River Vologda. Stratigraphical evidence as well as a conventional radiocarbon date (Le-5871, see Table 1 and Figure 10) suggested that at least part of these timbers stem from the Neolithic/Eneolithic period (Недомолкина 2004). Starting in 2007, joint Russian-German investigations have concentrated on multi-disciplinary research at the site, including geomorphological sampling, surface surveys, archaeometric analyses, and radiocarbon dating (Lorenz et al. 2012; Piezonka 2008; Недомолкина et al. 2014; Недомолкина and Пиецонка 2010). In 2015 a larger research project was granted by the German Research Foundation (DFG) to the German Archaeological Institute and later transferred to the Institute of Pre- and Protohistory at Kiel University, enabling new test trenching at the site as well as targeted research towards a diachronic assessment of human-environment interactions and palaeo-landscape reconstructions within the frames of Russian-German cooperation. A multidisciplinary approach of archaeological, geoscientific, archaeobiological, and biomolecular investigations is being employed for the first time in this region in order to reconstruct the dynamics of the environment and of land use as well as the development of economy and diet over eight millennia.

Materials and Methods

Recent fieldwork

A first joint Russian-German survey campaign at Veksa in 2011 was devoted to the creation of a digital plan of the pile concentration and to initial geomorphological drillings. Very low water levels had led again the exposure of the wooden remains, enabling the precise recording of their location on a 3D topographical plan, using a Leica TCRP 1201+ total station. In 2013, test trenches followed up the unexpected findings in the drillings of cultural layers further up to one hundred meters away from the bank of River Vologda (Lorenz et al. 2012; Недомолкина et al. 2014, 2015; Недомолкина and Пиецонка 2010). In 2014, dredging works along the River Vologda resulted in a partial disturbance and covering of the pile concentration by extracted sediments, and in 2015, the archaeology team in cooperation with members of the Vologda Diving Club conducted an underwater survey of the area to verify whether the pile settings documented in 2011 were still in place (see Figure 5). In 2015 and 2016, four test trenches (Russian: shurf) have been excavated in different sections of the river bank at Veksa 1 and 3, among which trenches 2 and 3 at Veksa 3 are relevant for the investigation of the wooden pile concentration. The excavations were supplemented by extensive series of drillings to assess the geomorphological situation on and around the site and to gain near-site pollen profiles.

Test trenches 2 and 3 at the river bank of Veksa 3

Test trench 2 was situated at the modern river bank in the area of the main concentration of wooden piles and stakes dating to the Late Neolithic/Early Metal Age transition around and just after 3000 cal BC (Piezonka et al. 2016; Недомолкина et al. 2015). In 2015, an initial area of 6 x 1 m was opened perpendicular to the river bank. Its aim was to investigate whether the pile concentration continued into the riverbank beyond its exposed portion, and if so, to document its position within the archaeological stratigraphy (Figure 5). In 2016 the trench was extended to a total of 12 square meters in order to fully excavate a large fish trap found in its south-western part (Figure 6). During the 2015 and 2016 campaigns numerous wooden remains and structures in excellent condition were found within the sediments of the river bank in trench 2, including

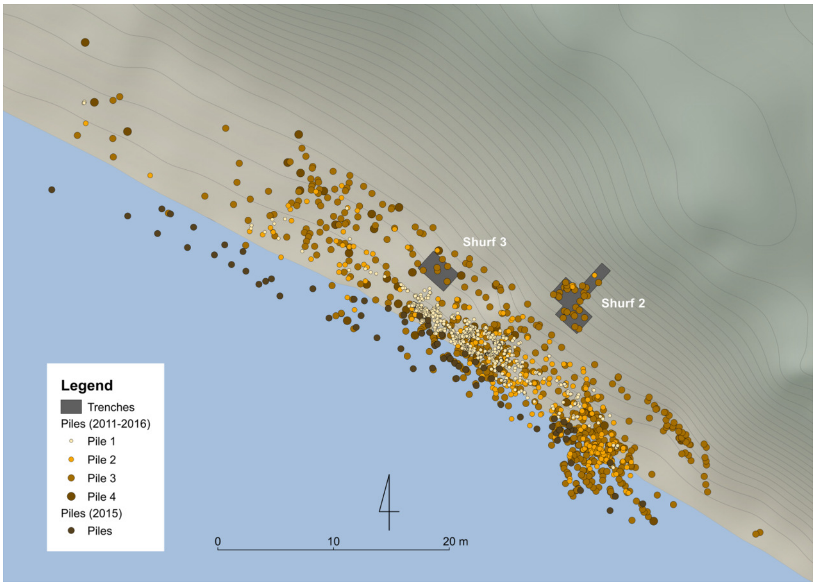

Figure 5: Veksa 3. The main pile concentration, showing four diameter classes for the piles documented in 2011 and in Trench 2, and additional piles documented by divers under water in 2015 without distinction of diameter classes. Diameter classes: 1 — 0–3 cm, 2 — 3–5 cm, 3 — 5–10 cm, 4 — 10–15 cm. Illustration Christoph Engel.

Figure 6: Veksa 3. Excavation trenches 2 and 3 seen from the river, summer 2016. Photo Nadezhda Nedomolkina.

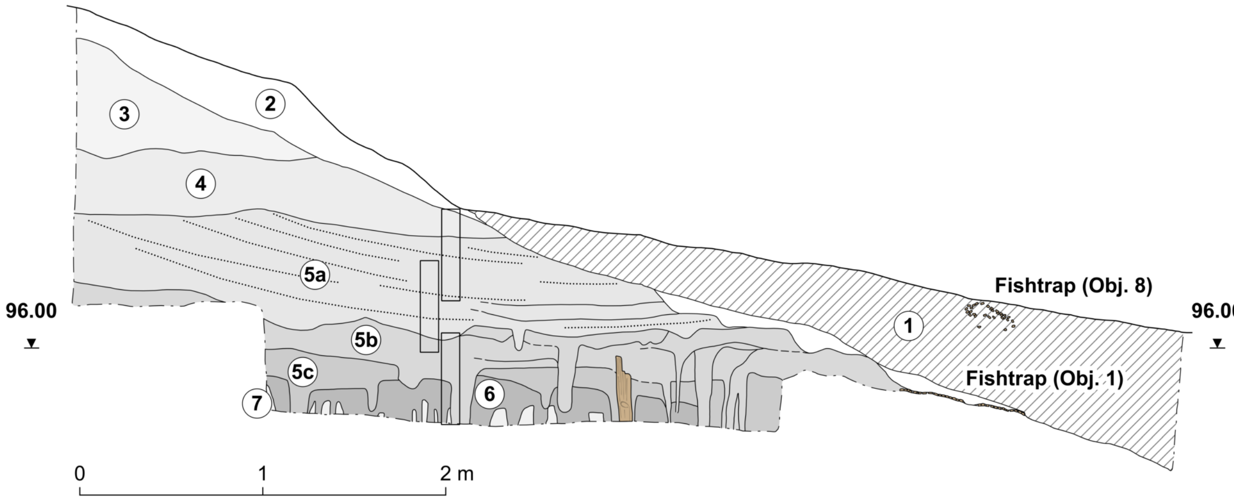

Figure 7: Veksa 3, trench 2. Eastern wall of excavation in 2015. 1 — layer 1, spoil heap of river dredging works in 2014; 2 — layer 2, topsoil before dredging works in 2014; 3 — Bronze Age layer 3 (c. 2nd half of 2nd millennium cal BC); 4 — Bronze Age layer 4 (c. 2nd half of 2nd millennium cal BC); 5a — Early Bronze Age layer 5a (c. 2nd half of 3rd millennium cal BC); 5b, c — Eneolithic layers 5 b, c, later phase of pile settings (c. 1st to 2nd quarter of 3rd millennium cal BC) with wooden post in situ; 6 — Eneolithic layer 6, early phase of pile settings (around 3000 cal BC); 7 — paleolake clay sediments layer 7; boxes: metal box soil samples; heights: relative to internal site system. Illustration Christof Engel, Henny Piezonka.

fragments of five fish traps and remains of post constructions with several upstanding posts. Approximately ten meters to the west of trench 2, another small test trench was opened in 2016 around a concentration of worked wooden battens visible on the surface (test trench 3, see Figure 5, Figure 6).

Geomorphological investigations

The general sedimentary succession for the archaeological complex of Veksa is concluded from 38 drillings reaching a depth of 4–8 m which cover an area of 10 ha from the eastern part of Veksa 1 to the west of the Veksa course to the eastern periphery of Veksa 3. The drillings extended up to 250 m north from the current northern bank of River Vologda. All 38 drillings with stratigraphical and pedological purpose were operated with percussion gaugers (60 mm and 80 mm diameter, 1 m and 2 m length, Stitz Company, Gehrden/Germany) with extension rods, gasoline percussion hammer, ball clamps, and mechanical rod pullers. Immediately after the drilling process the sediment stratigraphies were cleaned, photographed as well as described in the fields. The sedimentological and pedological documentation followed the 'Bodenkundliche Kartieranleitung, KA5' (Ad hoc AG Boden 2005), the national German mapping instructions for soils and sediments. For sedimentological and palynological analyses additional liner cores were taken at three sites in vicinity of Veksa river as well as at three sites within the adjacent Molotov palaeolake. We used a percussion piston corer with polyethylen (PE) liner tubes of 50 mm diameter with 1 m or 2 m length (Stitz Company, Gehrden/Germany). Before splitting and sampling, the cores were logged for magnetic susceptibility using a Bartington MS2C core logger. The splitted cores were photographed and sampled each centimeter. Every second sample was used for sedimentological analyses, every tenth sample for palynological investigations. Sedimentological investigations comprised car-

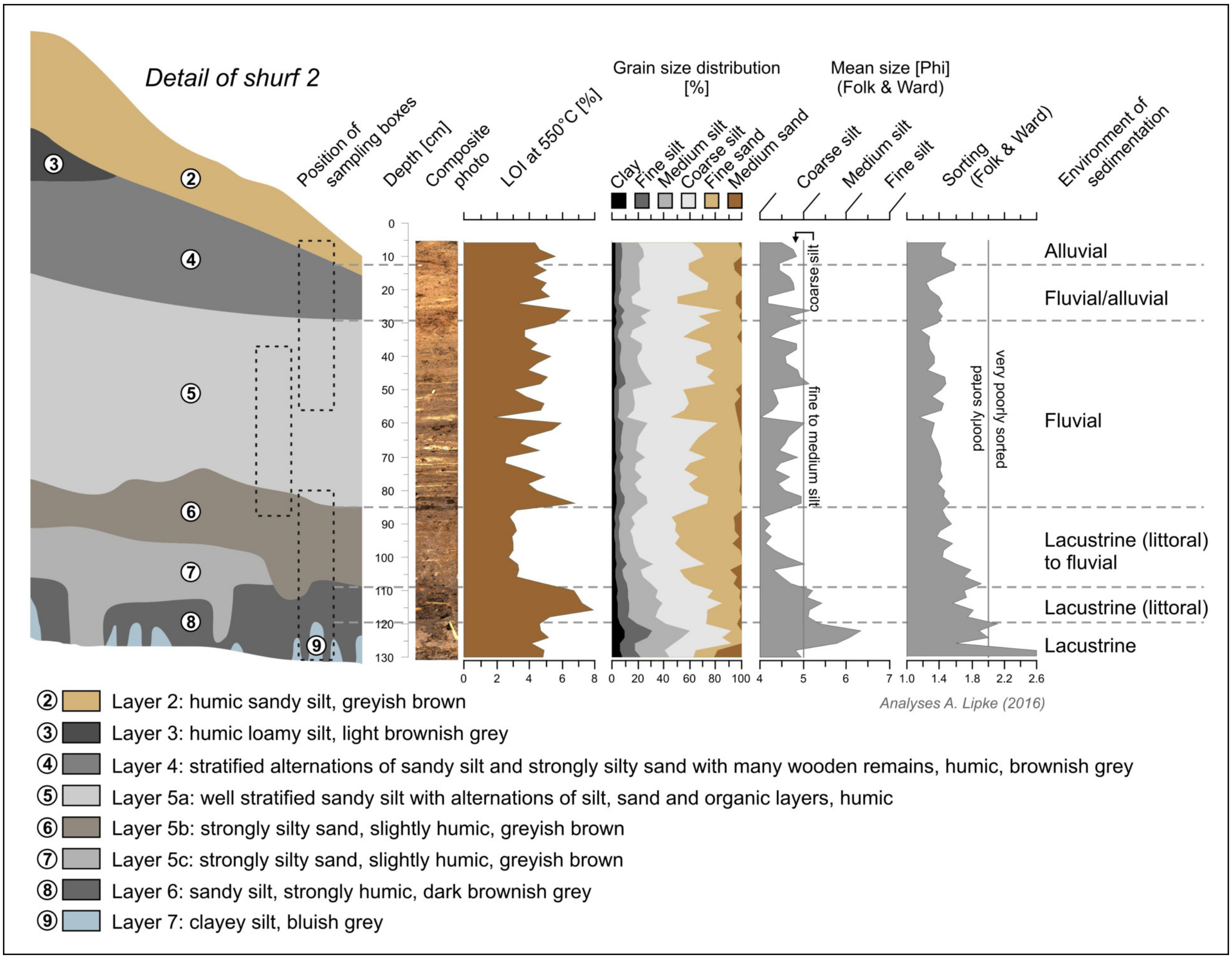

Figure 8: Veksa 3, trench 2. Stratigraphical and sedimentological units based on the analysis of the box samples (indicated by dashed lines on the profile drawing). Ilustration Sebastian Lorenz.

bon content (TOC, TIC) and grain size analyses with a laser particle sizer (FRITSCH Analysette 22 Microtec). Test trenches and archaeological excavations were sampled with self made metal sampling boxes of 15 x 15 x 45 cm size, which were hammered into the profile, afterwards released, sealed carefully and sampled with comparable procedures like done with liner cores. At the site of Veksa close to the dense occurrence of wooden posts along the river bank at area, the cliff section has been investigated by the archaeological test trench 2, and from its eastern profile, a box sample column was taken for sedimentological and archaeobotanical investigations (Figure 8; see also Figure 7). The information from the profile and the box samples was supplemented by three drillings along a transect up to 20 m from the river bank (see Figure 5).

Archaeobotanical investigations

Palynology: In the course of the Russian-German project, near-site and on-site pollen analyses have been conducted at Veksa and its vicinity for the first time. The results of the near-site core of VKS16 (a liner core extracted in the course of the geomorphological drillings) are discussed

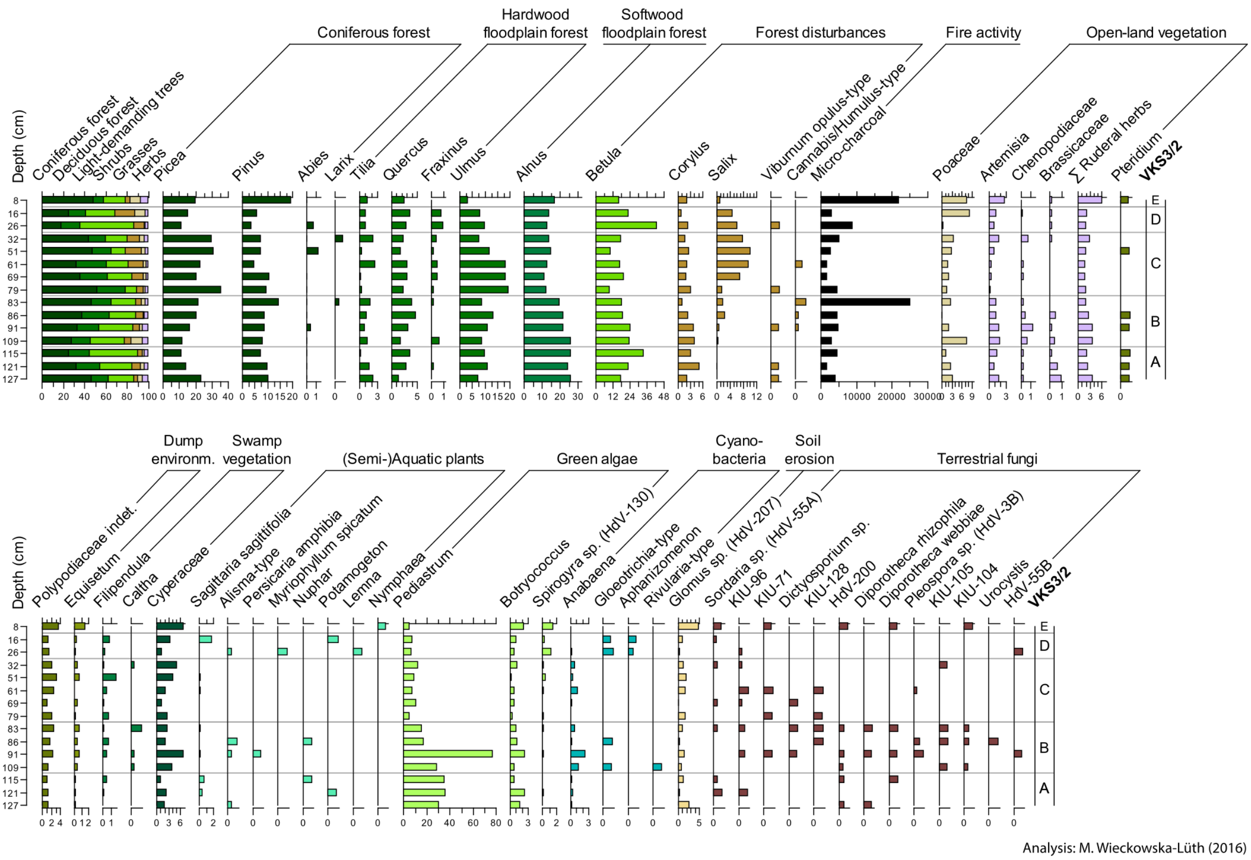

Figure 9: Veksa 3, trench 2, box samples. Simplified percentage diagram of palynological results, showing selected pollen taxa, spores, and non-pollen palynomorphs. Percentages are based on the sum of terrestrial pollen (AP+NAP) excluding wetland and aquatic pollen types. Microscopic charcoal particles are presented as black bars showing concentration in cm^3 sediment (location of box samples: see Figure 7). Graphics Magdalena Wieckowska-Lüth.

elsewhere (Kirleis et al. accepted). On-site pollen and non-pollen palynomorphs (NPP) analyses at Veksa 3, trench 2, were conducted on sediments from the box sample column cut out from the excavation profile using overlapping sample boxes (see Figure 7). Its sediment consisted of alluvial deposits. For palynological studies, fifteen sediment samples were taken at distinctive stratigraphical transitions in the profile. The samples were prepared for the analysis of pollen and NPP according to the standard techniques outlined by Moore et al. (1991). Nomenclature of pollen types follows Beug (2004) and that of spores Moore et al. (1991). NPP were identified using a reference catalogue at the University of Kiel and available literature (Hawksworth et al. 2016; Van Geel 2001; Van Geel and Aptroot 2006; Van Geel et al. 2003, 1989, 2011; Vánky 2013). Unknown NPP found in the samples are termed as 'KIU-xxx' (KIU = Kiel University). On average, 350 arboreal pollen (AP) grains per sample were counted due to low pollen concentration. The calculation of pollen percentages is based on the total terrestrial pollen sum (trees, shrubs, and dwarf-shrubs + pollen of herbaceous terrestrial plants or non-arboreal pollen [NAP], respectively), excluding wetland and aquatic pollen types. The data from the microscopic charcoal analysis are expressed as concentration per cubic centimetre of sediment. The diagram was produced with the help of the program C2 version 1.7.7 (Juggins 2014) (Figure 9).

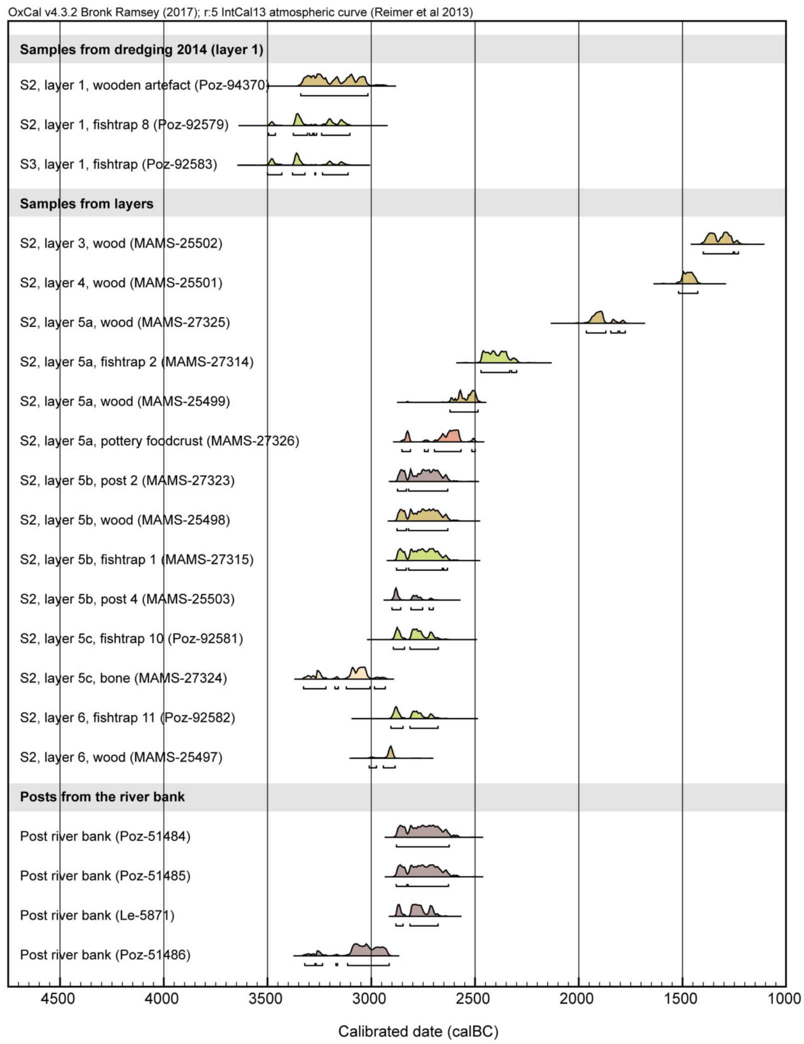

Figure 10: Veksa 3. Radiocarbon dates from the northern of River Vologda including pile concentration, trenches 2 and 3 (see also Table 1). Dark brown — posts, light brown — wood pieces, green — wood from lath screens, yellow — bone, red — foodcrust from pottery. Graphics Henny Piezonka.

Macrobotanical remains: Macrobotanical investigations on material from Veksa 3, trench 2, contribute to the reconstruction of the local environment. Eleven soil samples from the cultural layers 5a–c and 6 were investigated with respect to the content of macrobotanical remains (Table 3, see Figure 7). From the layers 5a and 6 three samples, respectively, were analysed, while four samples stem from layer 5b and one from layer 5c. Samples from layer 5a are located landwards (squares IV–VI). All other samples originate from the squares I–III closer towards the river. For analyses of the 1 mm and 0.3 mm fractions, 0.5 l of sediments were treated with the wash-over method to gain the small-seeded remains (Jacomet 2007). As bigger plant remains tend to be underrepresented in such small samples (Antolín et al. 2017), in addition 2 l of sediment were treated in the same way by use of 2 mm sieves to gain a representative number of seeds and fruits larger than 2 mm. Altogether 14.274 (0.3–1 mm) plus 3.714 (> 2 mm) water-logged plant remains (seeds, fruits, and vegetative remains) were identified. Find concentrations for remains < 1 mm reach in average 1.300 and for remains > 2 mm 34 per 0.5 l.

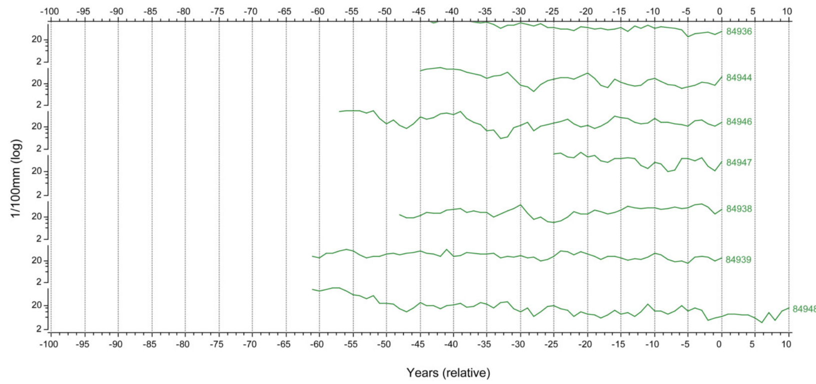

Figure 11: Veksa 3, trench 2 and adjacent riverbank. Tree ring curves of seven sampled posts from Veksa 3, see Table 2. Graphics Karl-Uwe Heußner.

Radiocarbon dating and dendrochronology

One of the main aims of the Russian-German cooperation work at Veksa was the creation of a comprehensive series of radiocarbon dates and other chronological evidence in order to better understand the temporal dimension of the cultural sequence at this site. From the riverbank at Veksa 3, a total of 21 radiocarbon dates exist now (Table 1, Figure 10). Among them are four dates on piles from the pile concentration, three of which stem from upstanding posts sampled in 2012 *in situ*. Fourteen dates come from various archaeological horizons in trench 2, among them two dates of upstanding posts, four dates on fish traps, six dates on unworked fragments of wood, one date of a bone from a large mammal, and one date on a pottery food crust. Three dates were received for samples that were found in the spoil of the dredging of the river bank in 2014 which was called layer 1 in trenches 2 and 3. Among these are two dates on fish traps and one date of a wooden artefact.

Due to the excellent state of preservation of most wooden artefacts on and in the river bank at Veksa 3, there is also good potential for dendrochronological studies. As a pilot study, 13 samples collected during the 2015 field campaign were analysed at the dendrochronological laboratory of the German Archaeological Institute in Berlin (Table 2). Ten of the samples (nos. 4–8, 10–13, Ufer 3) stem from posts that had been dislocated by the dredging works at the river bank in 2014 and were found lying on the surface of the excavated soil in the area of the post concentration. It is very likely that these posts had originally been part of the post concentration. Three samples come from the excavated layers in trench 2, two of them also from the spoil of the dredging works (layer 1, see Figure 7) and one from a post in layer 5.

Results

The development of the local environment

Geomorphological results

The archaeological complex of Veksa is situated within the wide-stretched basin of the Late Weichselian proglacial Lake Sukhona. Nowadays this basin comprises the River Sukhona, originating from Lake Kubena, the

River Vologda and beside others, the small River Veksa, which is originating from the shallow Lake Molotov which has been severely hydromeliorated since the 1980s (see Figure 2). Within the proglacial lakes several decameters of glaciolacustrine sediments, mainly clay and silt, were accumulated. A sediment core from the western fringe of Lake Molotov, which was part of Sukhona palaeo-lake, revealed 40 m of lacustrine sedimentation since the Valdaj Late Glacial (site N1: Gey et al. 2001). Due to the final decay of the glaciers, the lake levels of the proglacial lakes dropped, transforming them into several smaller lakes and exposing Late Glacial lake terraces 10–20 m above the recent basin surfaces (120–130 m a.s.l.; Kvasov 1979; Lunkka et al. 2001).

The plain surface of the Sukhona basin and its fine grained sediment inventory strongly influence the recent hydrography with low flow velocities and the suspension of enormous loads in the rivers. The humid boreal climate determines large annual water-level fluctuations of 3–4 m: During summer and autumn the river banks are exposed as 3–4 m high cliffs, while in spring time high water levels lead to extensive floodings and alluvial sedimentation in surrounding areas. The annual fluctuations of water levels as well as the alluvial sedimentation induce strong channel dynamics and have created a dense network of active rivers, backwaters, and shallow lakes (see Figure 2).

There are two fossil geomorphologic features which probably had an impact on the formation of the archaeological structures at the riverbank area of Veksa 3 in the late 4th and the 3rd millennium cal BC. The first are linear structures which probably represent fossilised beach ridges of a larger palaeo-lake phase of Lake Molotov (Figure 2, white dashed lines). In comparison to recent river channels the linear structures show clearly differing radiuses or even missing loops, which makes a lacustrine or littoral origin more probable. Secondly there is an abandoned, fossilised river channel east to River Veksa, which shows a good parabolic congruence to the present River Veksa (Figure 2, blue dashed line). Putting sedimentological and morphological evidence together, Lake Molotov developed during the gradual decay of Lake Sukhona and during the first half of the Holocene was much larger than it is today. Intense fluvial sedimentary influx and the evolving drainage system lead to a gradually diminishing in size of the lake basins, while a more hierarchic network with larger and tributary rivers developed. At some stage River Veksa came into being as an outflow of Lake Molotov, meandering at the bottom of the former Lake Molotov, but close to the larger River Vologda. Meanders of both rivers came closer to one another, until River Vologda tangentially eroded the banks of River Veksa and thus created its current confluence.

The general sedimentary succession for the site of Veksa is concluded from the 38 drillings between 4 and 8 m in depth:

1. The lowermost sediments are light to bluish clays, lacking macroscopically discernible organic remains. Only four drillings reached these sediments in more than 3.5 m depth. The clays are classified as sediments from the deeper (profundal) parts of the Late Glacial Sukhona paleolake. Gey et al. (2001, p. 1351) describe these glaciolacustrine clays with more than 14 m thickness also for the adjacent Lake Molotov.
2. Above the clays, silty silicate gyttjas with varying humic contents and light to dark grey color succeed. They occur in 2–8 m below surface,

show embeddings of sandy layers and they are rich in small wooden remains and partly also molluscs. The coarsening of the sediments is regarded as an indicator for a remarkable decline of the lake level and the diminishing lake area and volume. The organic remains point to a Holocene lacustrine sedimentation, the sandy layers to fluvial influx or lake-level fluctuations.

3. The present surfaces consist of 2–3 m thick alluvial loam, which shows intense reddish colors of hydromorphic influence and gleyic soil formation. Their origin is the annual flooding and the suspended river loads in springtime. The loamy sediments represent a fluvial drainage system at a place of former lakes. The persistent reworking and resedimentation of older (glacio)lacustrine sediments is leading to a strong similarity of younger alluvial and older lacustrine sediments. Due to intense drying during summer, the alluvial loams have a higher bulk density than the lacustrine silts. They are also lacking a discernible stratification because of bioturbation.

Despite their close spatial relation, there are distinct stratigraphical differences between the sediment layers in test trench 2 at Veksa 3 (Figure 8) and the adjacent banks of River Vologda roughly 2 m above the excavation pit. The lowermost sediments in Shurf 2 are bluish grey glaciolacustrine silts (layer 7). Their clay content of 6–9 per cent reaches maximum values for the entire profile. Its very poor sorting supports the genetical classification as a lacustrine sediment accumulated in deep water. Layer 7 is disturbed by the superimposed layers 5b, 5c, and 6, which cut as post-hole fillings into the lacustrine sediments. The pronounced differences in organic carbon content (LOI) point to a hiatus between layers 6 and 7. A chronological framework is given by several ^{14}C datings (see Figure 10): layers 5c and 6 were accumulated around 3000–2650 cal BC, the top of layer 5b dates back to 2550 cal BC. Only layers 5b and 6 were covered by sedimentological sampling. Layer 6 is characterised by high (7–8 per cent), layer 5b by low but stable organic carbon contents (LOI). The loss on organic contents is accompanied by coarsening of the mean grain size (fine sand), indicating increasing sedimentation dynamics in shallow waters. The slightly better sorting also points to an increasing influence of currents and wave turbulences. A broad variety of archaeological findings as well as shape and structure of layers 5b to 6 classify these horizons as cultural layers, which formed in littoral sediments. As far as the ^{14}C ages of the (mostly wooden) archaeological finds are taken as sediment ages, a landscape of small and shallow lakes existed until ca. 2500 cal BC in the vicinity of the site of Veksa, while the lake shores were settled. Most probably the lakes were connected by rivers. Layer 5a started to form around the middle of the 3rd millennium cal BC and is characterised by a distinct change of sediments and a concave sloping stratification (see Figure 7). Numerous plant and wooden remains lead to high LOI values (6–7 per cent). Also the comparatively good sorting indicates a fluvial sedimentation environment, while the well preserved lacustrine layers underneath point to a non-erosive, but accumulating sedimentation with little or any hiatus. The mean water level is expected to have fluctuated well above the sediments. The onset of layer 4 is again distinguished by a layer rich in organic content, indicating a calm sedimentary environment of a lake or backwater. In layer 4, dating to the Bronze Age around 1500 cal BC, well stratified sediments continue bearing several larger wooden remains. Together with their horizontal alignment layer 4 is classified as partially fluvial, but mainly of alluvial origin during floodings. The uppermost layers

2 and 3 (not covered by sediment samples) represent poorly sorted allocated or colluvial floodplain sediments of the present river bank.

In summary, the Late Stone Age wooden constructions at the modern river bank at Veksa 3 were erected in slighty streaming or still waters. From a sedimentologic point of view, the post constructions and fish traps were probably placed at the diminishing Lake Molotov as well as across the evolving small River Veksa.

Palynological results

Based on the different sediment layers, five local pollen assemblage zones (VKS3/2 [Veksa 3/Trench 2] A–E) were distinguished in the pollen diagram from the stratigraphical sequence in the box sample column (Figure 9, see also Figure 7, Figure 8). The two oldest zones VKS3/2 A–B, which are encompassing the archaeological layers 6 and partly 7 (zone A) and 5b (zone B), in general display a high amount of arboreal pollen. *Alnus* (alder) is the dominant tree taxon during this time, demonstrating a softwood floodplain forest adjacent to the water body. At the same time, the presence of *Ulmus* (elm) pollen mirrors a hardwood floodplain forest on higher terraces, admixed with other broad-leaved tree taxa, such as *Quercus* (oak), *Fraxinus* (ash), and *Tilia* (lime). Conifers, such as *Picea*, *Pinus*, *Abies*, and *Larix*, are also present within the pollen record. Except for the latter, however, they probably represent the contribution of pollen transported over long-distances. Elevated amounts of *Corylus* (hazel) and *Viburnum opulus*-type (guelder-rose) may indicate small-scale openings in the forest, whereas the relatively high proportions of *Betula* (birch) reflect succession stages within the lowland woodland. In accordance with this, the occurrence of the *Humulus/Cannabis*-type, most probably representing common hop, points to open sites within the floodplain forest.

The stage represented by VKS3/2 A–B is also characterised by slightly elevated amounts of open-land indicators such as ruderal herbs, in particular *Artemisia* (mugwort), Chenopodiaceae (goosefoot family), and Brassicaeae (cabbage family) as well as the fern *Pteridium* (bracken). The values of Poaceae (grass family) fluctuates strongly, whereby the sample in the depth of 109 cm has the highest amount. Micro-charcoal is present in all samples of this section, reaching its highest quantity at 83 cm depth. During this phase, there is also evidence of pollen of littoral and aquatic plants such as *Sagittaria sagittifolia* (arrowhead), *Alisma*-type (water plantain), *Nuphar* (pond lily), *Persicaria amphibia* (water knotweed), and *Potamogeton* (pondweed) in the pollen record. The presence of those taxa indicate standing water or, respectively, low flow conditions of the water body, as high velocity in general prevent the setting up of aquatic plants. At the same time, the high amounts of green algae, in particular, *Pediastrum* and *Botryococcus* may also point to stagnant or slow-moving water, because only those habitats are important for the development of phytoplankton.

In contrast to VKS3/2 A, the following VKS3/2 B contains more evidence of pollen of swamp plants such as *Caltha* (marsh marigold), *Filipendula* (meadowsweet), and Cyperaceae (sedges) suggesting, at least temporarily, somewhat drier conditions than before. At the same time, the slight rise in the proportions of Polypodiaceae indet. (ferns) and *Equisetum* (horsetail) may demonstrate the progressive spread of terrestrial vegetation towards the water body. Contemporaneously, more frequent occurrence of ascospores of terrestrial fungi, among them decomposers (e.g. *Sordaria* sp., HdV-55B, *Dictyosporium* sp., *Pleospora* sp.), plant parasites (e.g. *Diporotheca webbiae*, *Diporotheca rhizophila*, *Urocystis* sp., HdV-200), and others (e.g. KIU-96, KIU-71, KIU-128, KIU-105, KIU-104) probably demonstrates their proliferation on dead and decaying terrestrial plant material in highly productive shallow water biotopes during periodical drying. The simultaneously elevated evidence of Cyanobacteria (*Anabaena*, *Gloeotrichia*-type, *Rivularia*-type) may be indicative of increasing water eutrophication, which could be associated with nutrient enrichment during a lowering of the water table and/or due to human activities.

In VKS3/2 C, which corresponds to archaeological layer 5a, the abundance of light-demanding woody taxa, such as *Betula* and *Corylus* decreases slightly, along with ruderal herbs and *Pteridium*, whereas the values of *Ulmus* increase visibly. This may indicate fewer open areas in the hardwood floodplain forest during this time. The values of microscopic charcoal particles also drop to some extent, pointing to decreased fire activity. Within the softwood floodplain forest, the proportion of *Alnus* diminishes, whereas the amounts of *Salix* (willow) increase significantly. This suggests the existence of frequent pioneer habitats contiguous with the water body. Open areas alongside the watercourse are also demonstrated by the presence of Cyperaceae and *Filipendula*. Such sites commonly occur during periods of high stream velocity. Changes in flow dynamics are also indicated by the disappearance of pollen of most aquatic and amphibian plants in parallel to the marked decrease in green algae and cyanobacteria. In addition, still occurring records of terrestrial fungal spores in the alluvial deposits may be associated with soil erosion processes responsible for their input to the water. In accordance with this, slightly increased finds of chlamydospores of *Glomus* sp. verifies such inputs of erosional material into water.

The following zones VKS3/2 D–E, corresponding to layers 4 and 2, respectively, are characterised by the renewed occurrence of pollen of littoral and aquatic plants such as *Sagittaria sagittifolia*, *Alisma*-type, *Nymphaea* (water lily), *Myriophyllum spicatum* (Eurasian watermilfoil), *Lemna* (duckweed), and *Potamogeton*, whereas the abundance of *Salix* diminishes gradually, indicating increasingly calm waters during this time. Shallow, stagnant water conditions are also verified by the appearance of the green alga *Spirogyra* sp. At the same time, increased proportions of cyanobacteria (*Aphanizomenon*, *Gleotrichia*-type) may be indicative of elevated levels of nutrients in the water.

Macrobotanical results

The water-logged macrobotanical plant remains from trench 2 at Veksa 3 in general represent the vegetation of the shoreline of a meso- to mainly eutrophic waterbody with its typical zonation (Table 2). Ubiquity values show a regular presence of aquatic and riverine plants as well as tall forbs. The wet grasslands and ruderals are less well represented. The vegetation complexes that connect landwards, the marginal vegetation, the local willow belt and alder carr are indicated by numerous remains. The high representation of coniferous forest shows a regional signal of alluvial allochthonous plant material. According to the macrobotanical analyses, the local vegetation indicated by the material deposited in layers 5a (lower part), 5b, 5c, and 6, can be described as vegetation on the shore of a mainly eutrophic waterbody with either stagnant or slow-flowing water. Ecological indicators show periodical flooding of the riverbank. The ruderal flora hints towards high anthropogenic impact on the vegetation, as it can be expected for a site where fishing and other human activities took place. The stratigraphical differentiation of the deposition of the cultural layer 5a if compared with 5b or 6 is hardly indicated by changes in the macrobotanical assemblage here. This is most possibly an effect that the soil samples originate from the lowermost part of layer 5a, thus representing only the onset of the changes of the waterbody towards an increased flow velocity that is detected by the sedimentological and palynological analyses. The fine layering of the sediments above, that were deposited under the highly dynamic water flow of the proceeding period were not promising to contain any seeds and fruits.

From an archaeobotanical point of view the waterlogged plant remains from this trench allow for reconstruction of the natural environment at the shoreline of the former waterfront. The macrobotanical remains indicate a nutrient rich water body, shallow water-conditions with stagnant to slow-flowing water and periodical flooding of the riverbank. A shift towards increased flow velocity is not observable here, because only the lowermost part of layer 5a was sampled due to the fact that the uppermost fine layers were not suitable for the preservation of macrobotanical remains. There is no macrobotanical indication for any dietary contribution of plants from this trench. However, some taxa identified by pollen analyses owe the potential to be used as dietary supplement, but hard evidence is missing.

Human activities at the river bank in the Late Stone Age

The pile concentration

Archaeological timbers that are upstanding in the sediment at the northern bank of the River Vologda are distributed in several clusters along a 350 m long stretch of the left river bank between the Veksa mouth and the eastern part of the Veksa 3 site (Figure 3). Neither on the water side nor on the land side the edge of the distribution has been reached during the documentation (see Figure 4). In the shallow water, numerous piles were documented, and it is very likely that many more posts and stakes are preserved under water. On the land side, the posts continue into the river bank sediments as can be seen by many examples barely exposed at the foot of the steep slope. During the initial topographical survey in 2011, four different size classes were distinguished. Altogether, a total of 1.802 piles and rods were documented, 786 with diameters between 0–3 cm, 402 with diameters of 3–5 cm, 569 with diameters of 5–10 cm, and 45 with diameters of 10–15 cm (Nedomolkina and Piezonka 2014; Недомолкина et al. 2015). In the course of the survey and excavations in 2015 and 2016, further upright timbers were found in the shallow water of River Vologda and in trench 2 (Figure 5, Figure 12). The larger posts consist of natural tree stems, in some cases with the bark still preserved, with a round cross-section. The lower ends of these posts have been pointed with axe blows

(Figure 12). Most of the larger posts and stakes stand upright in the sediment, although some of them have already been washed out by the river and were found lying loosely on the ground, and the dredging works in 2014 have further disturbed and dislocated posts.

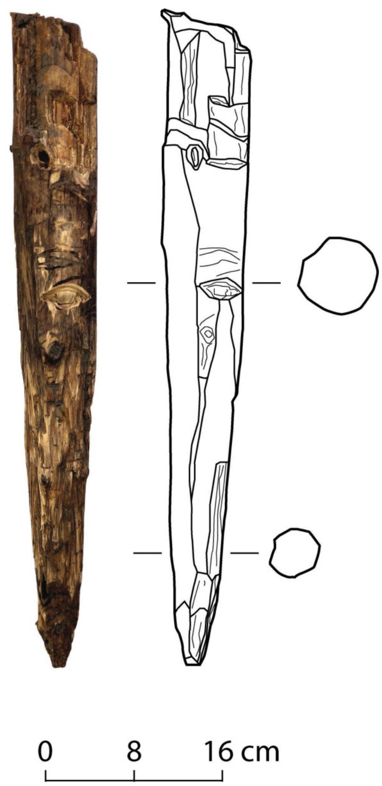

Figure 12: Veksa 3, trench 2. Pile no. 7. Photo and illustration Henny Piezonka.

The largest concentration of piles is located c. 100 m west of the old excavation trench of Veksa 3 and covers an area of c. 65 x 10 m (Figure 5). Here, significant differences in the distribution of the four size classes were noted. The smaller rods (up to 5 cm diameter) form dense localised concentrations and are now, with the excavation results from test trench 2, understood to represent remains of fish traps and fish fences (see below). In contrast, the posts with diameters between 5 and 15 cm are distributed over larger areas and are partly arranged in straight parallel and perpendicular lines. The orientation of these structures does not exactly correspond to the course of the river but is slightly offset, indicating a change of the river course and hydrological regime since the time of building of the pile constructions, a hypothesis which is also supported by the geomorphological and archaeobotanical findings.

Test trench 2 was positioned perpendicular to the river course with the aim to clarify the character and function and the stratigraphical position of the timber structures (Figure 5–Figure 7). During the excavation, 30 further upstanding piles were found *in situ* (27 with diametres between 5–10 cm, and three measuring 3–5 cm) (Figure 5; Figure 13). All of them are associated with layers 5b, 5c or 6 (see Figure 7 for an example of the stratigraphical position of one of the piles). These three layers are also characterised by hundreds of post holes of various sizes that extend into the sediments below. From layer 6 three post holes are cutting into the subsoil (layer 7) that consists of blue clay formed in a periglacial lake during the Pleistocene/Holocene transition (Lorenz et al. 2012). Post holes originating form layers 5b and 5c partly also reach as far down as the palaeolake clay. In the two square meters of excavation squares IV and V alone, 158 post and stake holes were cutting into the clay subsoil of layer 7, alongside with 6 posts still *in situ*. This abundance of post holes in this part of the stratigraphy indicates a very dynamic use of the area by people erecting, dismantling and re-building wooden constructions. As the excel-


Figure 13: Veksa 3, trench 2. Group of upstanding piles in the northwest corner of excavation area 2016. Photo Henny Piezonka.

lent preservation of wood in these layers is proven by the *in situ* posts and other wood and plant remains, it is clear that the post holes must stem from intentionally extracted timbers and not from posts that decayed *in situ*. The results from trench 2 therefore indicate that the ca. 650 upstanding posts of the two largest diameter categories documented at the river bank represent just a very small fraction of all timbers that had been set into the ground in this area during the phase in which layers 6, 5c, and 5b accumulated. The time frame of this phase ranged, according to the radiocarbon dates, from ca. 3000 to 2600 cal BC, the period of transition from the Late Stone Age to the Early Metal Ages (Table 1, Figure 10). It is the phase when this area was characterised by shallow, probably stagnant or only slightly flowing water and by human activity in the vicinity, as indicated by the sedimentological, palynological results and by the plant macroremains. Above this horizon follow layers of river sediments that formed during the Bronze Age (layers 5a, 4, 3) which produced only a small number of archaeological finds (see Figure 7).

A total of six posts from the pile concentration have been radiocarbon dated: four upstanding posts from the riverbank, and two from test trench 2 (Table 1, Figure 10). The two posts from the trench and three of the posts from the river bank produced almost identical dates between ca. 2900 and 2600 cal BC, while one post from the river bank appears several centuries older (Poz-51486, 4410±35 BP). Very interesting results are provided by a dendrochronological pilot study during which thirteen posts from the river bank were assessed (Table 2, Figure 11). All of the samples of this pilot study stem from dislocated posts that were found in the area of the main pile concentration at Veksa 3, most of them had been disturbed by the dredging works in 2014. Their association with the main pile field can be assumed. In general, the timbers are characterised by comparatively narrow rings with small trunk diameters. In most cases the timbers have been felled after the end of the yearly growing period, only sample no. 84938 has been cut during the vegetation period. In six samples, the ring sequences were too short to be assessed. Of the remaining seven samples, six have been felled in the same year while one sample (no. 84948) as been cut ten years after the others. These results indicate that the posts at the Veksa 3 river bank bear substantial potential for dendrochronological investigations and that through a more extensive study it might be possible to identify contemporary structures within the pile field. Due to the good potential indicated by this pilot study, a larger dendrochronological analysis of *in situ* posts from Veksa 3 in association with radiocarbon dating (wiggle matching) is planned.

The lath screens

One of the outstanding results of the archaeological excavations in the trenches 2 and 3 at Veksa 3 is the discovery of the remains of six lath screens, five in trench 2, and one in trench 3 (Figure 14–Figure 23). Like the other wooden remains in this part of the river bank, the organic materials of these features are exceptionally well preserved due to waterlogging. From modern, ethnographical and archaeological comparisons it is clear that these lath screens represent parts stationary fishing equipment such as fish traps and fish fences (e.g. Koivisto and Nurminen 2015; Sirelius 1906; Lozovski et al. 2013b). Common features that all examples at Veksa share are that they consist of pine wood and that the laths have

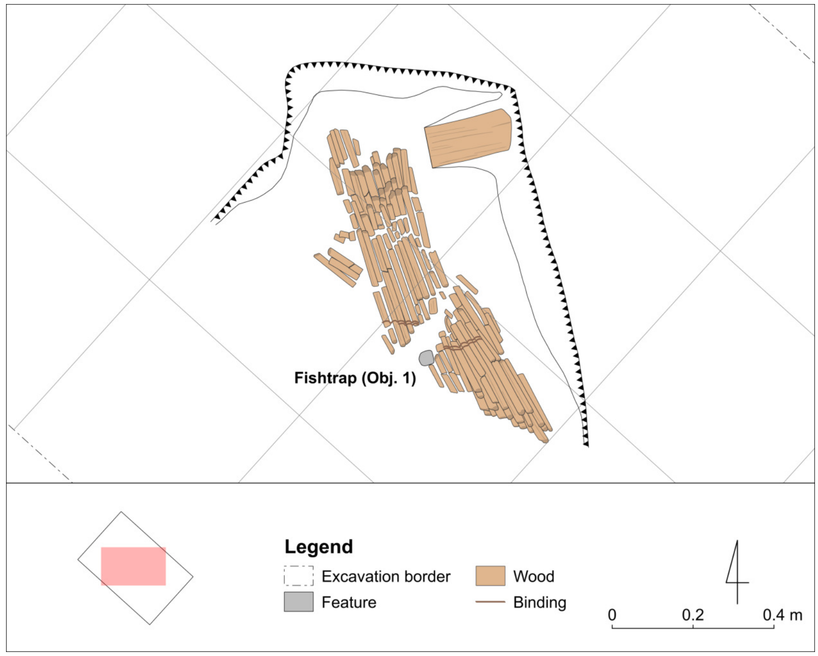

Figure 14: Veksa 3, trench 3. Fishtrap found in sediments re-deposited in 2014 during drainage works. Graphics Christoph Engel.

Figure 15: Veksa 3, trench 3. Fishtrap found in sediments re-deposited in 2014 during drainage works, seen from the east. Photo Marina Tydo.

rectangular cross sections. The lath screens excavated in test trenches 2 and 3 are associated with different layers and time periods (Figure 10, Figure 14, Figure 17).

The two oldest examples stem from the disturbed sediments that had been extracted from the river and were deposited on the riverbank during the dredging works in 2014. According to radiocarbon dates, they both stem from around 3500–3100 cal BC. Object 1 from trench 3 consists of a dense parcel of lath fragments measuring ca. 95 cm in length and ca. 27 cm in width (Figure 14–Figure 16). The laths are approximately 2 cm wide and 0.5–0.6 cm thick. This lath screen is the only one at Veksa so far where fragments of the organic binding (probably bast?) have been preserved (Figure 16). Likewise from the dredging spoil came object 8 in trench 2 (Figure 17, Figure 18, see also Figure 7 for location in the profile).

Figure 16: Veksa 3, trench 3. Detail of fish-trap with remains of organic binding. Photo Marina Tydo.

It also consists of rather substantial laths of ca. 1,5 cm wide and 0.7 cm thick and was preserved at a lengths of ca. 90 cm.

Among the stratified lath screens, the lowermost is object 11, a fragmented fishtrap made of very fine laths of only 0.5 to 0.7 mm width and 0.2 to 0.4 mm thickness (Figure 17, Figure 19). It is associated with layer 6 and has been partially destroyed by a later post hole which again illustrates the dynamics of the use of this formerly lacustrine zone. A radiocarbon date places it within the main activity phase between ca. 2900 and 2700 cal BC. An almost identical date was received for object 10 from layer 5c, another small fish trap made of thin pine laths, in this case between 0.5 and 0.7 cm wide and 0.3 to 0.4 cm thick (Figure 17, Figure 20). Its documented maximal length is ca. 40 cm, but it continues into the southwestern profile of the excavation trench.

Only marginally younger is object 1 of trench 2 which was associated with layer 5b (Figure 17, Figure 21, Figure 22, see also Figure 7 for location in the profile). This lath screen can be traced on a length of more than 3 m, at its well-preserved middle part it measures ca. 50 cm in width. It runs almost north-south and has for its size rather thin laths of about 1.3 to 1.7 cm in width and ca. 0,5 to 0.7 cm thick.

Substantially younger is object number 2, a fish trap found at the base of layer 5a which is associated with the change in the hydrological regime from lacustrine to fluvial (Figure 17, Figure 23). A radiocarbon date places this object in the third quarter of the 3rd millennium cal BC. The dimensions of the laths are similar to those of object 1. Its entire preserved length cannot be judged as the feature runs into the northwestern wall of the trench. Directly on top of it lay a long, band-shape wooden object with a carved pointed end which might have been used for fixing the fish-trap in the intended position.

In summary, the lath screens documented at the river bank at Veksa 3 belong to different types, the larger ones probably representing lath screens of fish weirs (object 1 of trench 3, objects 8 and possibly also 1 and 2 of trench 2) and the two smaller ones (objects 10 and 11 of trench 2) are probably the remains of small fish basket-like traps that might have been used in connection with fish weirs. Chronologically, the documented laths

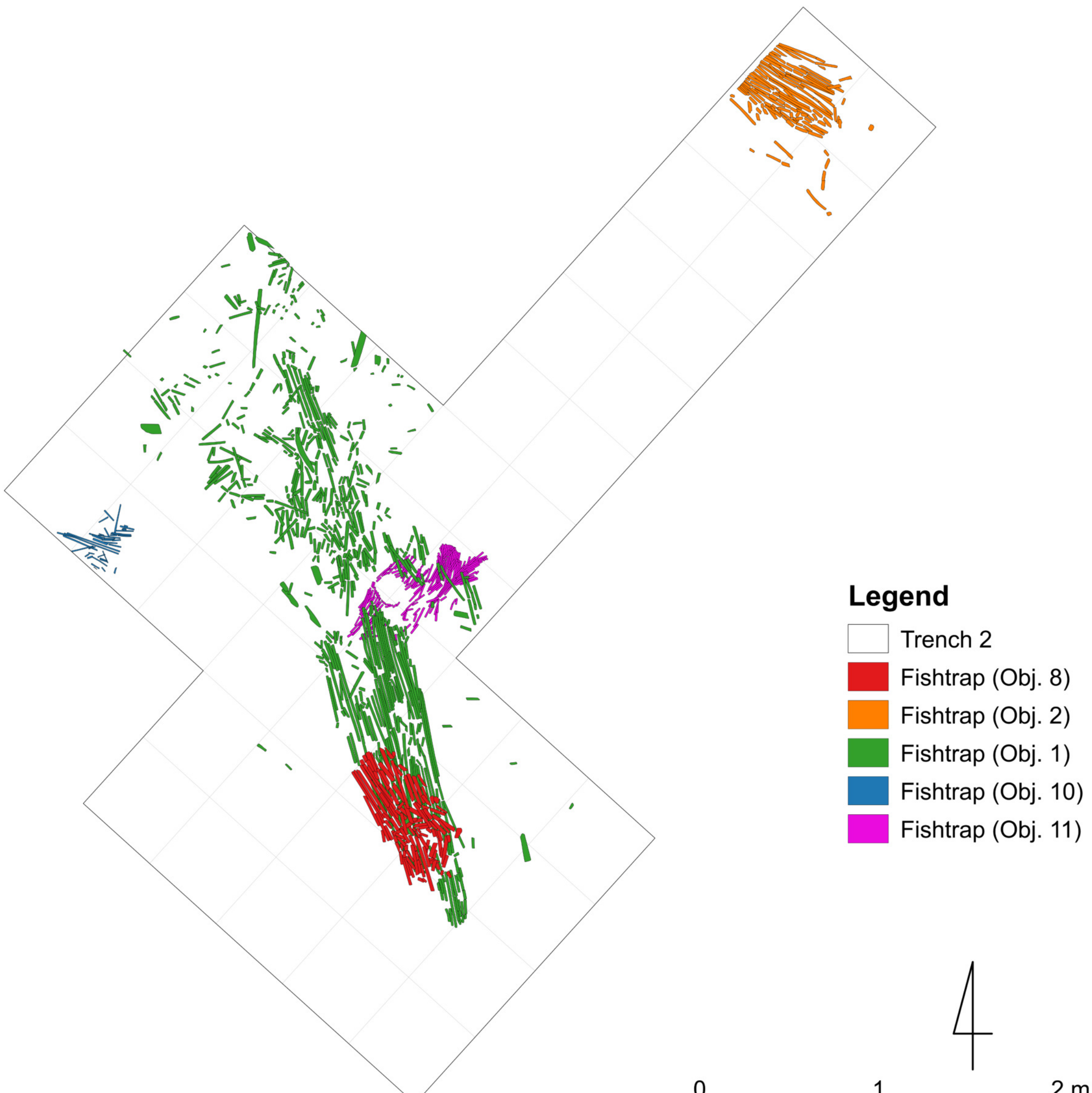

Figure 17: Veksa 3, trench 2. Overview of lath screen remains interpreted as fish traps/fish fences. Graphics Christoph Engel.

Figure 18: Veksa 3, trench 2. Fishtrap (object no. 8). Photo Marina Tydo.

Figure 19: Veksa 3, trench 2. Fishtrap (object no. 11). Photo Marina Tydo.

screens cover a period of more than thousand years, from the middle of the 4^{rth} to the second half of the third millennium cal BC (see Figure 10).

Other finds

The find material from trench 2 is, in comparison with other excavation areas at Veksa 1 and 3, not particularily abundant, which is due to the fact that the sediments preserved here probably do not represent dwellings remains and associated cultural horizons but lacustrine and fluvial accumulations which contain artefacts deposited here mainly through the action of water. A particularity, however, is the good preservation of organic materials (bone, wood) under the prevailing waterlogged conditions. Finds from layers 6, 5c, and 5b, the horizon associated with the

Figure 20: Veksa 3, trench 2. Fishtrap (object no. 10). Photo Marina Tydo.

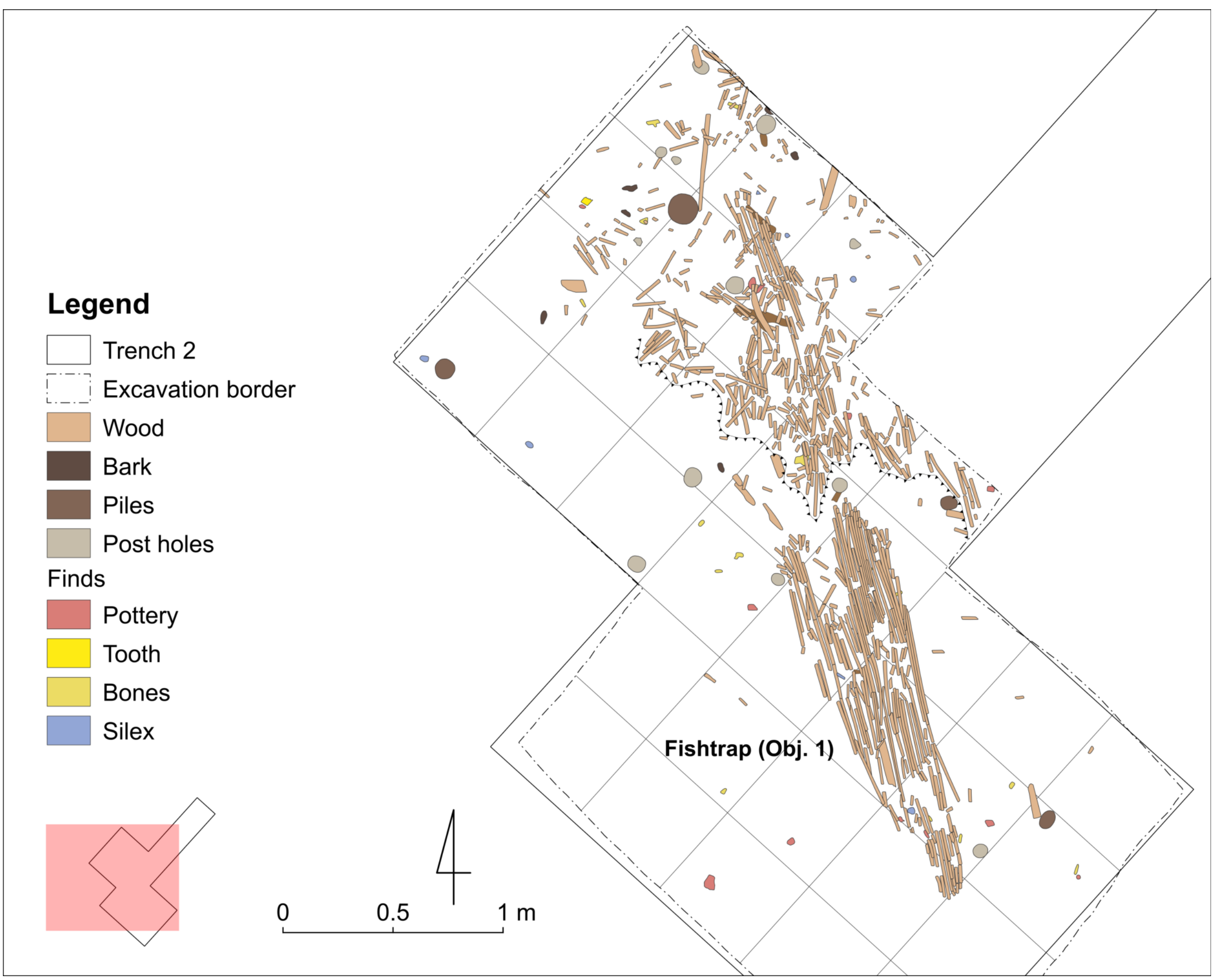

Figure 21: Veksa 3, trench 2. Fishtrap (object no. 1). Graphics Christoph Engel.

Figure 22: Veksa 3, trench 2. Fishtrap (object no. 1) seen from NNW. Photo Marina Tydo.

Figure 23: Veksa 3, trench 2. Fishtrap (object no. 2). Photo Henny Piezonka.

post and lath screen structures, include pottery (mainly organically tempered pourous ware that is typical for the Eneolitic period in the Sukhona region; Figure 24, 1–2), some bone artefacts and numerous remains of animal bone, a few worked wooden remains, and lithic artefacts. Layer 5a produced still less finds, although here, too, a worked wooden tool an some pottery have been found. Of interest is a large sherd of a ceramic vessel that is typologically linked to the Final Neolithic Fatyanovo culture pottery (Figure 24, 3). Foodcrust from the interior surface of the vessel yielded a radiocarbon date in the second quarter of the 3rd millennium cal BC (see Table 2 and Figure 10), which is in accordance with the chronological framework of the Fatyanovo culture but seems a few centuries too old according to stratigraphy. The reason for this could be a freshwater reservoir effect. From the spoil of the 2014 river dredging (layer 1), for worked wooden artefacts with oblique points have been found. All of them are broken, but on one of them it visible that the other end also had been shaped into an oblique point. Their function is unclear at the

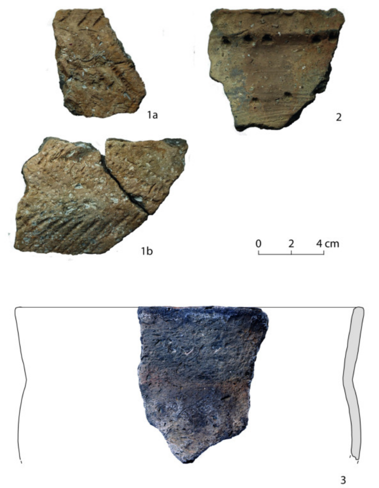

Figure 24: Veksa 3, trench 2. Pottery fragments of the Eneolithic “porous ware” from layer 5b (1–2) and of Fatyanovo type ware from layer 5a (3). Photos and illustration Henny Piezonka and Marina Tydo.

Figure 25: Veksa 3, trench 2. Four wooden artefacts found in sediments re-deposited in 2014 during drainage works. Second left: dating sample Poz-94370 (4460±35 BP). Photo Marina Tydo.

moment. A sample from one of the artefacts yielded a date in the late 4th millennium cal BC (see Table 2 and Figure 10).

Discussion

Landscape development and human impact

Central results of the palaeoenvironmental investigations at the river bank of Veksa 3 encompass the development of the landscape in the course of the Holocene and the character and intensity of human-environment interactions. A general observation concerns the substantial annual fluctuations of the water table which have affected this area over much of the Holocene period and thus have restricted the possibility of human settlement to the higher areas of the banks and terraces. Based on geomorphological assessment of the land surface in the upper Sukhona basin and the sedimentological results of drillings, we suggest here that east of the modern River Veksa, an abandoned, fossilised river channel bears witness of a former meander of the Veksa that at some stage merged with the course of River Vologda, leading to the establishment of the current Veksa mouth (see Figure 2, blue dashed line). This previous situation has probably provided the environmental background for the construction of post structures and fish traps in an area of stagnant or slowly-flowing water, which is very different from today’s dynamic fluvial regime at this location.

In test trench 2, the stratigraphical sequence also shows evidence for a substantial change in the hydrological regime during the period of human use in the Late Neolithic and Early Metal Ages. The stratigraphy includes the following main phases:

1. Lacustrine sediments consisting of bluish clayey silt that represent the Late Glacial Sukhona palaeolake.
2. Littoral lacustrine sediments consisting of strongly humic silty sands that have accumulated in an area of stagnant or slowly flowing water. This phase is dated to the mid-4th to mid-3rd millennium cal BC and thus covers the Late Neolithic and Early Metal Ages. This is the period when the area was intensely used by people who erected, dismantled and rebuilt post constructions and fish traps in this shallow water area. The presence of a mainly eutrophic waterbody with either stagnant or slow-flowing shallow water as well as substantial anthropogenic influence in the vicinity are clearly indicated in the palynological record and the botanical macroremains from this horizon.
3. Fluvial and alluvial sediments consisting of stratified sandy to loamy silts which accumulated in a river bank area of a flowing water body. These sediments started to accumulate in the mid-3rd millennium cal BC and thus indicate a substantial change in the hydrological regime at this site from stagmant/slow-flowing waters to a river. This change which is also well documented in the palynological record runs concurrently with the end of the intensive human use of this place, and archaeological remains are now restricted to a few stray artefacts. In the investigated profile at trench 2, this phase is documented well into the Bronze Age up until the second half of the 2nd millennium cal BC.

Chronology

From an archaeological point of view, the thousands of man-made timbers and wooden artefacts preserved in the river bank area at Veksa 3 represent an exceptional and extremely valuable archive for the understanding of landscape use, settlement history and economy in this part of the Northeast European forest zone and beyond. These findings include hundreds of wooden posts with pointed ends that are set vertically into the sediments, and the remains of numerous lath screens interpreted as remains of fish traps and fish fences, of which six have been documented during the recent excavations.

The radiocarbon dates in connection with stratigraphical observations appear to indicate three phases of the activities connected to these structures (see Tab. 1, Fig. 10). Five dates (two lath screens, one post, one wooden artefact, and one animal bone) stem from the second half of the 4th and the very beginning of the 3rd millennium cal BC. Three of the sample have been found in the spoil of the river dredging in 2014 and it is therefore possible that sediments of this older phase have been preserved mainly further down the river bank in the modern river bed of the Vologda from where they have been extracted during the river dredging works. In the undisturbed archaeological sediments documented in trench 2, this phase is apparently not represented, as almost all dates from layers 6, 5c, and 5b belong to the first half of the 3rd millennium. The only exception is the mentioned animal bone fragment (MAMS-27324, 4436±25 BP) which falls into the early phase. As the bone belongs to a large ungulate (bovid or cervid, pers. comm. N. Benecke, German Archaeological Institute, Berlin), it is not very likely that a freshwater reservoir effect is responsible for the comparatively ancient dating result. This could only be a possibility if the bone stems from an elk, as elks can consume aquatic plants in amounts that can affect their radioccarbon age (Philippsen 2019). As the majority of the other dates from layers 6–5b stem from stationary *in situ* structures and are therefore reliably associated with this stratigraphic unit, it seems possible that the dated bone fragment could have been relocated in antiquity and might stem from the older activity phase. Chronological phase 2 encompasses the already mentioned series of dates from the layers 6, 5c, and 5b (samples from three lath screens, two posts, two unworked wood fragments), and three dates of *in situ* posts from the unexcavated parts of the pile concentration. This phase covers the period from ca. 3000 cal BC until ca. 2600 cal BC. A possible third phase of human activities in this area is indicated by the single lath screen from layer 5a which was found at the very base of this stratigraphical unit and produced a date in the third quarter of the 3rd millennium cal BC. Interestingly, this lath screen is also the one furthest up the river bank in this area, thus representing another indication of a possible horizontal stratigraphy, in which the oldest structures are located down the bank in the current river bed towards the south, and the later structures further up the bank, more towards the north. The other two dates from layer 5a stem from samples further up in the stratigraphy. While the wood sample points to a Bronze Age date for the accumulation of layer 5a, the food crust date that stems from a Fatyanovo-type pottery vessel (Fig. 24) appears older. This might be due to a freshwater reservoir effect, a problem that has been repeatedly described for the Veksa materials and other North Russian sites both in Stone Age and in modern contexts (Piezonka et al. 2016, 2017). The two dates from layers 4 and

3, respectively, are in accordance with the stratigraphical sequence and point to an accumulation of these layers in the developed Bronze Age.

The pile and lath screen structures — remains of stationary fishing gear

Apart from the determination of the chronological association and time depth of the wooden structures observed at Veksa 3, one of the main aims of the current project was the better understanding of their character and function. Both the surface survey and the test trench excavations have succeeded in creating a comprehensive picture of the structures, their spatial distribution and constructive properties.

The lath screens, of which six examples have been partially or entirely excavated, can be interpreted as remains of small fish traps (objects 10 and 11 from trench 2) and larger screens probably stemming from fish fences (objects 1 and probably 2 from trench 2, object 1 from trench 3). All six documented lath screens are made of pine wood and consist of laths with rectangular cross sections. Based on this characteristic, they belong typologically to a northeastern European tradition of prehistoric fishing constructions, while further west in the western Baltic and southern Scandinavian regions, Stone Age fish traps tend to be made from either unworked twigs or from split timbers of that have been worked to an oval or rounded cross section. The main species used in this region are hazel, viburnum, and willow (Klooß 2015a, pp. 14–22).

Lath screens of various sizes similar to those excavated in Veksa that are made from coniferous laths with rectangular cross sections are widely known from Stone Age contexts in the Eastern Baltic, Finland, and the adjacient regions of the Russian forest zone. Among the oldest and most impressive examples are the well preserved Late Mesolithic and Early Neolithic lath screens of the late 7th and 6th millennia cal BC documented during underwater excavations in the Dubna bed at Zamostje 2 in Central Russia (Lozovski et al. 2013a). Examples from the 6th millennium cal BC have also been recorded at Karavaikha in Lake Vozhe basin in northern Russia (Kosorukova et al. 2016), younger evidence of post settings and lath screens interpreted as Late Neolithic and/or Eneolithic fishing structures has been found, for example, at Okhta 1 in Saint Petersburg (Gusentsova and Sorokin 2011) and Podol'e 1 on the southern shore of Lake Ladoga (Гусенцова and Кулькова 2016). In Finland, dated examples of prehistoric lath screens from fishing devices stem from the 4th and 3rd millennia cal BC and thus from the same period as the Veksa finds; among the most important sites is Purkajasuo near the northern end of the Gulf of Bothnia (Koivisto and Nurminen, 2015). Close typological parallels of the larger lath screens found at Veksa 3 are known from the Eastern Baltic region where similar structures, even with bast binding remains (such as the ones documented at object 1 from trench 3 at Veksa 3) have been recorded in various Stone and Early Metal Age contexts at sites such as Sarnate (Latvia) and Sventoje (Lithuania) (e.g. Rimantienė 2005, pp. 71–76; Bērziņš 2008, pp. 241–250). Based on ethnographical comparisons from Latvia and Western Siberia, Valdys Bērziņš (2008, p. 246) argues that lath screens preserved as bigger packages of several layers are the remains of rolled-up screens for fish fences, and not of actual fish traps, as had

Figure 26: Tanche-Mache, Taz region, Western Siberia, Russia. Wooden posts prepared by Selkup hunter-fishers in 2001 in advance for future use in the construction of fish weirs for winter fishing. Scale: one meter between left end of thin brown pine rod in the foreground and white mark at which the north arrow points. Photo Henny Piezonka.

Figure 27: Tanche-Mache, Taz region, Western Siberia, Russia. Remains lath screen of fish fence made by Selkup hunter-fishers in 2001 for winter fishing. Photo Henny Piezonka.

sometimes been suggested earlier. This is also in accordance with our interpretation of the larger examples from Veska (see above).

Ethnographic evidence represents a valuable source for the better understanding of prehistoric fishing methods and the associated structures, and it has been repeatedly consulted for finds from northern and northeastern Europe (e.g. Bērziņš 2008; Klooß 2015a,b; Koivisto and Nurminen 2015). A very important source is the comprehensive account of weir fishing of Finno-Ugrian peoples by the Finnish scholar Uuno T. Sirelius (Sirelius 1906). For our study, the numerous examples of fish fences in Sirelius' work that have been constructed from rows of upright posts, lath screens fixed to the posts, and removable fish traps attached to open passages in the screens are of special interest, as such constructions could account for the archaeological evidence recorded at the river bank of Veksa 3 (e.g. Sirelius 1906, 47, Fig. 84, 67, Fig. 132a, 73, Fig. 139b).

Up until today, comparable stationary fishing constructions are being used in parts of the Western Siberian taiga. In 2016 and 2017, a winter fish fence made by the local Northern Selkup that was last used in 2001 has been recorded at the River Pokal'ky, a tributary of the River Taz in the northern taiga zone (Figure 26, Figure 27). Two factors are especially interesting in connection with the evidence from Veksa: (1) A pile of prepared pine posts that were intended for later use in the re-erection of this fish fence consists of posts almost identical to the posts recorded at Veksa, including shape and dimensions, and also the bark left in place. Timber used in Selkup dwellings, in contrast, generally have the bark stripped off. (2) Valeri Irikov, a Selkup hunter-fisher that had been involved in the building of the fence, described the construction which consisted of the above-mentioned combination of stationary post rows, lath screen fixed to them, and removable fish traps attached to the passages left open in the fence. Irikov explained that the posts were driven into the river bed at distances of two man's feet from one another in a straight line across the river — a stucture that closely resembles the rows of posts at the river bank at Veksa.

Altogether, it is likely that the majority of wooden constructions recorded at Veksa 3 represent the remains of stationary fishing constructions and not of pile dwellings or other settlement structures. Sites that are interpreted as pile dwellings, for example Modlona or Serteya II in northern and western Russia, have certain other characteristics that are not present at Veksa, such as clear ground plans of (rectangular) buildings, and the presence of floor remains, cultural layers, and waste accumulations (Mazurkevich et al. 2010; Ошибкина 1978). Also, the immense dynamic of construction and dismantling of structures that is indicated by the presumably thousands of empty post holes from which the post had been drawn out, is better explained by stationary fishing constructions that have to be repaired and renewed virtually every year, rather than by dwellings and living platforms that would be long-lived. This said, it is nonetheless possible that some of the post structures at Veksa might have served as substructions of wooden footbridges or platforms on the dynamically used shallow water area at what is now the northern bank of River Vologda.

Conclusions

Recent archaeological investigations at the northern bank of River Vologda in the area of the site Veksa 3 east of the Veksa mouth have substantially furthered our understanding of the chronology, character and functions of the wooden constructions preserved in this area and of the human-environment interactions taking place during the Late Neolithic and following periods. A multidisciplinary approach within the frames of a Russian-German research project has been successfully applied to shed more light on this key site of the northeast European forest zone.

Geomorphological and sedimentological studies have been able to reconstruct three main phases of sedimentation that are represented in the riverbank sediments, including lacustrine sediments of the Late Glacial Sukhona paleolake, followed after a hiatus by lacustrine sediments of a stagnant or slow-flowing shallow water zone in the late 4th and early 3rd millennium cal BC, which are in turn covered by fluvial sediments indicating a substantial change of the local hydrological regime towards a dynamic riverbank around the middle of the 3rd millennium cal BC. It was also shown that the current mouth of the River Veksa is probably the result of a former meander of this small river merging with the larger River Vologda.

The wooden constructions at the river bank have been investigated by surface survey and by small test trenches in several field campaigns since 2011. They encompass thousands of archaeological timbers, many of them upstanding posts with pointed ends, and several lath screens, six of which have been excavated. Radiocarbon datings place the constructions within a time frame between the second half of the 4th and the first half of the 3rd millennium cal BC. They are associated with the lacustrine, shallow water phase identified in the palaeoenvironmental studies. Based on archaeological comparisons and on ethnographic information, it is likely that these wooden structures represent the remains of stationary fishing constructions that encompass rows of piles, lath screens, and fish traps.

Future work at this exceptional archaeological assemblage will include further systematic dendrochronological investigations as well as the assessment of the faunal remains. Excavations of larger areas within and around the main pile concentration have good potential to gain further insights especially into the organic parts of the material culture of the hunter-gatherer-fisher groups of the forest zone in the Late Stone and Early Metal Ages.

Acknowledgements

The authors would like to thank the many people that have participated in the archaeological fieldwork at Veksa over the last years and have made the results possible, among them Aleksandr Grudkov, Ilia Heit, Viktor Nedomolkin, Martin Oczipka, Jens Schneeweiß, Marina Tydo, and enthousiastic students and school children from Vologda and Tarnogo. Two student groups from the Dept. of Geography of Greifswald University have worked hard in the field, and two of them, Anne Lipke and Finn Schmidt, have written their Bachelor theses on materials from Veksa. Christoph Engel, Berlin, and Stefanie Klooß, Schleswig, have contributed their respective expertise on GIS and Stone Age fishing gear in the post excavation process. The work has been funded by the German Research Foundation (DFG grant no. PI 1120/2-1) and was further supported by the Eurasia Department of the German Archaeological Institute. We are grateful to the organisers of the session at the 2016 EAA conference in Vilnius for including our study in this edited volume.

Table 1: Radiocarbon dates from Veksa 3, river bank and trenches 2 and 3.

Lab. Code	Context	Material	Age ^{14}C	Err.
Poz-51486	River bank	Wood	4410	35
Le-5871	River bank	Wood	4180	20
Poz-51485	River bank	Wood	4160	35
Poz-51484	River bank	Wood	4155	35
MAMS-25497	Qu. V, Layer 6, E profile	Wood	4308	24
Poz-92581	Qu. BII-III, Layer 6, fishtrap 11	Wood (pine)	4220	35
MAMS-27324	Qu. V, Layer 5c, bone	Bone	4436	25
Poz-92581	Qu. Z'-AII, layer 5c, wood	Wood (pine)	4200	30
MAMS-25503	Qu. IV, Layer 5b, E profile, post 4	Wood	4221	24
MAMS-27315	Qu. II, Layer 5b, fishtrap 1	Wood (pine)	4160	28
MAMS-25498	Qu. III, Layer 5b, E profile	Wood	4153	27
MAMS-27323	Qu. II, layer 5b, post 2	Wood	4149	23
MAMS-27326	Qu. VI, Layer 5a, pottery	Foodcrust	4084	24
MAMS-25499	Qu. V, Layer 5a, E profile	Wood	4039	22
MAMS-27314	Qu. VI, Layer 5a, fishtrap 2	Wood (pine)	3910	28
MAMS-27325	Qu. 5, Layer 5a, wood	Wood	3553	23
MAMS-25501	Qu. VI, Layer 4, E profile	Wood	3207	24
MAMS-25502	Qu. VI, Layer 3, E profile	Wood	3052	23
Poz-92583	Shurf 3, Layer 1, fishtrap	Wood (pine)	4585	35
Poz-92579	Qu. CI-II, Layer 1, fishtrap 8	Wood (pine)	4570	35
Poz-94370	Qu. DII, Layer 1, wooden artefact	Wood	4460	35

Table 2: Results of dendrochronological pilot study of posts from Veksa 3.

Lab. No.	Wood species	Internal sample no.	Start	End	Felling	Notes
C				Relative date		
84936	Coniferous wood	1 (Bagger 3)	-45	0	0	Dull edge
84937	Coniferous wood	2	?	-	-	No date
84938	Coniferous wood	3 (2 I)	-48	0	1	Summer dull edge
84939	Coniferous wood	4	61	0	0	Dull edge
84940	Coniferous wood	5	?	-	-	Too short (13 rings)
84941	Coniferous wood	6	?	-	-	Too short (30 rings)
84942	Coniferous wood	7	?	-	-	Irregular
84943	Coniferous wood	8	?	-	-	Too short (31 rings)
84944	Coniferous wood	10	-45	0	0	Dull edge
84945	Alder	11	?	-	-	Too short
84946	Coniferous wood	12	-57	0	0	Dull edge
84947	Coniferous wood	13	-24	0	0	Dull edge
84948	Coniferous wood	Ufer 3	-61	10	10	Dull edge

Table 3: Absolute numbers of waterlogged plant remains (0.3-1 mm fraction) from Veksa 3, trench 2. x = present in the fraction 2 mm.

Sample numbers	**8, 11, 16**	**17, 162, 165-167**	**169-171**
Square	**VI**	**IV, Z III, B I-II, A III**	**B III, A II-III**
Cultural layer	**5a**	**5b,c**	**6**
Volume (Litres)	**0.5**	**0.5**	**0.5**
Aquatic plants			
Nuphar lutea	x	x	-
Potamogeton cf. *gramineus*	1	-	-
Potamogeton lucens	2	5	3
Potamogeton cf. *natans*	2	5	3
Potamogeton pectinatus	-	6	2
Potamogeton cf. *perfoliatus*	10	9	3
Potamogeton praelongus	-	1	1
Potamogeton spec.	9	8	4
(Herbal) Riverine vegetation			
Alisma spec.	173	39	26
Bidens tripartia	11	3	1
Butomus umbellatus	-	3	1
cf. *Carduus crispus*	2	-	-
Chenopodium album	66	28	37
Chenopodium glaucum/rubrum	22	144	172
Chenopodium spec.	x	-	6
Eleocharis palustris	26	13	21
Lycopus europeaus	2	-	-
Mentha aquatica	79	113	40
Oenanthe aquatica	219	189	58
Persicaria maculosa	18	15	9
Persicaria lapathifolium	28	50	18
Ranunculus sceleratus	2	-	-
Rumex maritimus	9	55	33
Sagittaria sagittifolia	68	130	159
Schoenoplectus lacustris	-	-	1
Schoenoplectus spec.	x	-	-
Solanum dulcamara	10	2	-
Tall forbs and marginal vegetation			
Filipendula ulmaria	141	104	15
Galeopsis spec.	2	-	1
Galium spec.	2	1	-
Stachys spec.	16	4	4
Thalictrum flavum	109	37	9
Urtica diocia	15	42	21
Wet grassland vegetation			
Carex (2) spec.	690	454	155
Carex (3) spec.	4	-	3
cf. *Cirsium palustre*	-	1	1
Cirsium spec.	-	3	-
Potentilla palustris	16	-	-
Potentilla spec.	2	-	2
Ranunculus acris	2	x	-
Ranunculus repens	2	-	-
Ranunculus spec.	82	9	1
Rumex crispus	-	5	3
Scirpus sylvaticus	5	-	-
cf. *Scirpus*	-	x	-
Silene flos-cuculi	5	-	3
Ruderal vegetation			
Fallopia convolvulus	2	-	-
Galium spurium	8	-	-
Plantago major	2	26	6
Polygonum aviculare	2	-	-
Solanum nigrum	-	3	1
Sonchus arvensis	-	-	1
Urtica urens	-	7	-

Sample numbers	**8, 11, 16**	**17, 162, 165-167**	**169-171**
Square	**VI**	**IV, Z III, B I-II, A III**	**B III, A II-III**
Cultural layer	**5a**	**5b,c**	**6**
Volume (Litres)	**0.5**	**0.5**	**0.5**
Deciduous forest (incl. shrubs and herbs)			
Alnus glutinosa	263	250	17
Alnus incana	282	545	27
Fragaria vesca	-	3	-
cf. *Fragaria*	6	-	-
Prunus padus	x	x	x
Rhamnus frangula (modern?)	x	-	-
Rosa spec.	-	1	1
Rubus fruticosus agg.	-	2	1
Rubus ideaus	x	3	-
Rubus spec.	2	-	-
Salix spec. (fruit capsule+A22)	16	922	293
Tilia cordata	3	-	-
Viburnum opulus	2	-	-
Coniferous forest (incl. shrubs)			
Betula spec.	52	97	79
Picea abies	9	32	18
Vaccinum myrtillus	5	-	3
Indeterminable			
Apiaceae	-	-	2
Asteraceae	-	4	2
Caryophyllaceae	2	-	-
Cyperaceae	8	4	5
Lamiaceae	2	2	2
Poaceae (small-grained)	-	8	-
Polygonaceae	-	-	3
Vegetative remains			
Alnus spec. (fruit scale)	x	3	1
Betula pendula (fruit scale)	4	3	2
Betula spec. (male inflorescence)	-	x	-
Picea abies (needle fragment)	2726	2493	110
Picea abies (fruit scale)	2	-	-
Picea abies (seed wing)+A74	4	4	2
cf. *Picea abies* (cone)	x	-	-
cf. *Picea abies* (cone scale)	x	x	-
Vegetative remains	10	21	4
Bud	151	38	14
Bud scale	1161	51	33
Leaf /bud	64	107	13
Miscellaneous			
Varia	2	x	-
Indet.	14	38	17
Sum	**6656**	**6145**	**1473**

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The settlements of the Kryvina peat bog region in the context of cultural changes of the 5th – 2nd millennium BC

6

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Kryvina peat bog is a micro-region with archaeological settlements of 5th–2nd millennium BC, located on the border of Beshankovichy and Sianno districts, Viciebsk region, in the southern part of the Belarusian Lakeland (Figure 1). It occupies a center of a large bog massif that was reclaimed and covered by a network of canals in the early-1930s–1960s. Peat extraction was held here during the 1960s–1980s. The total area of the Kryvina

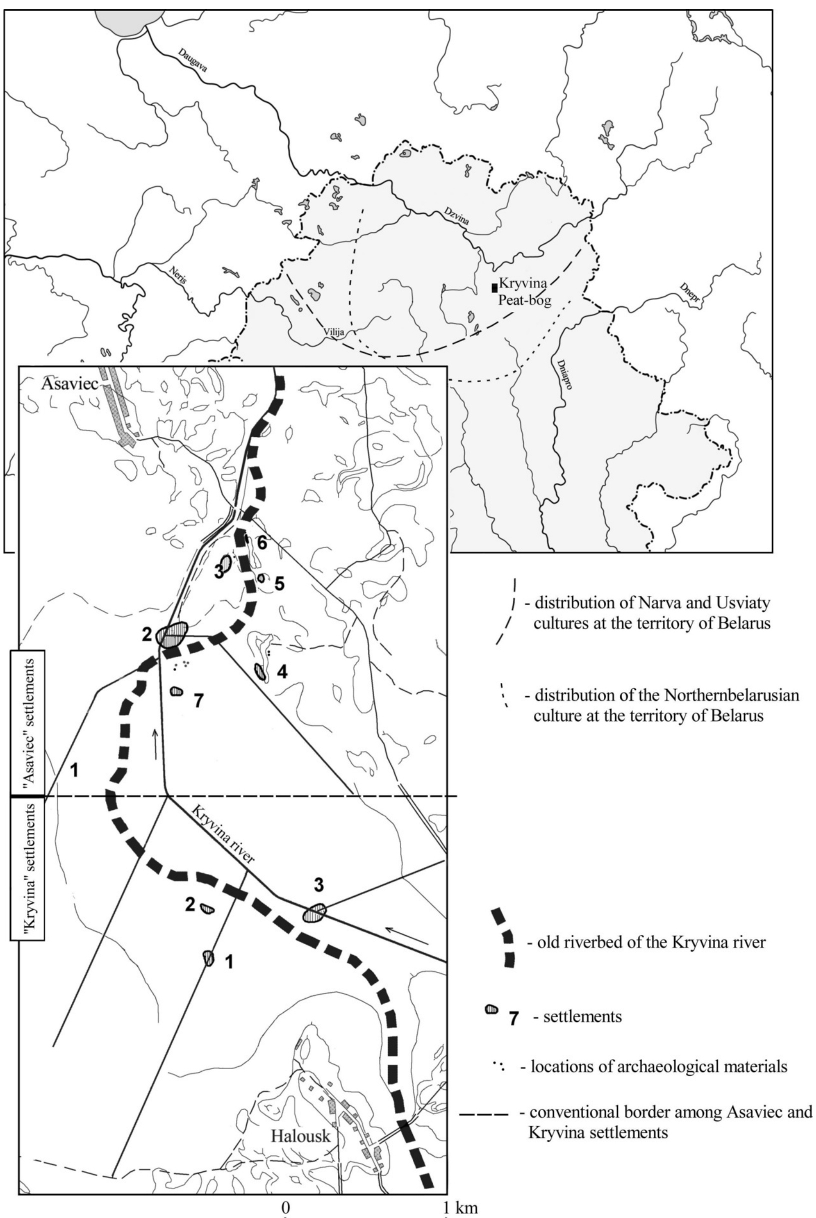

Figure 1: Localisation of the Kryvina peat bog and its settlements.

Charniauski, M. (2020). 'The settlements of the Kryvina peat bog region in the context of cultural changes of the 5th – 2nd millennium BC'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 95–109. DOI: 10.11588/propylaeum.714

peat bog is about 8 km^2. It is drained by the Kryvina River, a left tributary of the Dzvina (Daugava) River, which flows into the Baltic Sea.

The first archaeological site in the territory of the Kryvina peat bog was recorded in 1934 by Kanstancin Palikarpovich and Zmicier Kavalenia (Чарняўскі 2006, p. 16). It was the Kryvina 1 settlement. From 1966 to 2012, Michal Charniauski was the main researcher of the region. The author joined his research in 2000 and has been working there until present.

There are ten settlements at the Kryvina peat bog known today, namely Asaviec 1–7 in its northern part, and Kryvina 1–3 in the southern part (Figure 1). There are also six other locations of archaeological material known here. Nine settlements retain organic materials in the cultural layer (except the Asaviec 6), eight of which are covered by the peat (except the Asaviec 4). Asaviec 4 and Asaviec 6 settlements were badly damaged by outcrop mines in the 1970s. The location of the Asaviec 1 settlement was lost after a peat fire in 1939 (Чарняўскі 2006, p. 16).

Kryvina paleolake and its surroundings were a complicated ecosystem with different landscapes and soils, rich flora, and fauna (Симакова 2000). Lower levels of the surrounding landscape were formed by sedimentary lacustrine sands, while upper levels were formed by sandy-gravel and clay hills. A large part of the paleolake was swamped and became peaty. Alder, birch, and scrubby pine brushwoods were typical for these areas. It was a rich territory with various berries, including raspberry, cranberry, red bilberry, blackberry, etc. Birch and pine woods were also typical for sandy and sandy-gravel areas. Clay-loam and clay soils were covered by fir forests. Various fauna species occupied different landscapes, including elks in dark spruce groves, deers, and roe deers in pine forests, wild boars in broadleaved and mingled woodlands, beavers in the river and lake creeks, etc. (Разлуцкая 2010). There were different waterfowls on the surface of the river and the lake, as well as different fishes. Species of the fishes varied in accordance with the lake development. In the early Neolithic, the lake was sufficiently deep to provide comfortable conditions for catfish, whose bones dominate the ichthyological materials of the Asaviec 4 settlement (Narva culture). Late Neolithic and Bronze Age regressions activated processes of growing over of the lake. The shallow areas that were formed became ideal places for pike and perch, whose bones dominate in materials of Usviaty and Northernbelarusian cultures (Ляшкевіч 2010, pp. 292–93).

According to palynology, human presence in the Kryvina peat bog region since 6500 BP is recorded (Симакова 2000, p. 52). K. Palikarpovich mentioned the location of flint artefacts without pottery at the southern main shore of the peat bog (not researched), which could be linked with the Mesolithic. There is information about the same location of flint materials found in the northern valley wall of the peat bog, which might belong to Kunda culture (Чернявский 2003, p. 94).

Kryvina Peat bog during the 5th–4nd millennium BC

Asaviec 4 site is the most ancient settlement excavated in the Kryvina peat bog. Its material almost entirely belongs to the Early Neolithic Narva culture (Чернявский 2003, p. 94). The settlement is located 2 km south-east to the village Asaviec on a gravel hill. During Neolithic time, there was an

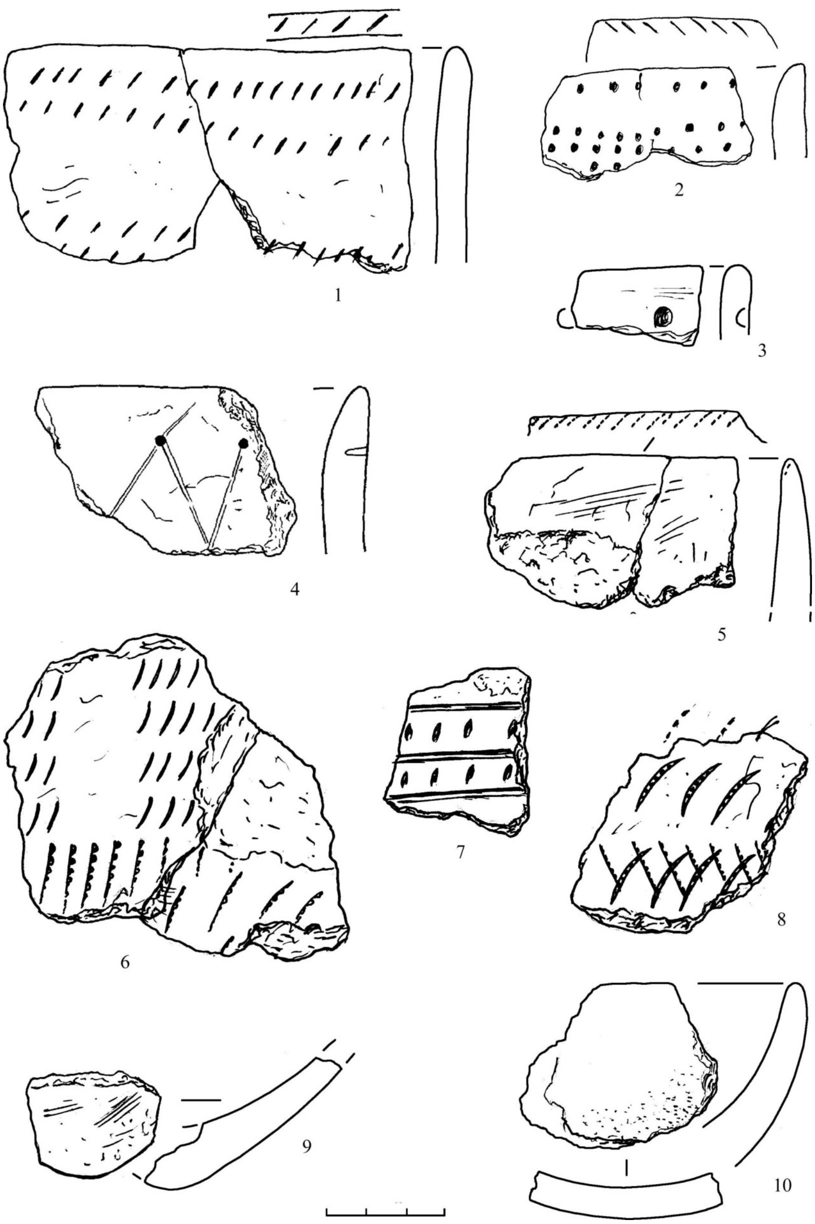

Figure 2: Asaviec 4 settlement. Pottery of the Narva culture. 1–9 – fragments; 10 fragment of bowl. From the materials of Michal Charniauski.

island where this site was founded. It was recorded in 1972 and investigated by Michal Charniauski between 1977 and 2004. Due to the presence of gravel and calcareous ground in the cultural layer, some organic materials were preserved. Furthermore, pottery, flint, and bone artefacts were found at the settlement (Чернявский 2012, p. 88).

Pottery of the Narva culture is represented by fragments of wide opened pots with convex sides, sharp-blunt bottoms, and straight, slightly bent inwards, or slightly curved rims. Their edges are thickened or rounded. There are also fragments of bowls, including oval forms. Fibrous organic remains, fine organics, and crushed shells were used as temper material. The vessels were formed from coils that were mainly joined to one another by 'U'-type connection. The off-set pinching was also used, albeit quite seldom. The outer and inner surfaces of vessels were covered by scratches left by a comb stamp. Ornamentation concentrates in the upper parts of the vessels and on the rims (Figure 2). The edges of the rims are not usually decorated. The inner part of the edge and inner surface of the pots are slightly more frequently decorated. About 20 per cent of the pots were decorated by a line of deep round pits or pin impressions under the rim.

Almost half of the ornamented rims are decorated with a variety of pinholes. There are also long and short notches, and comb prints. In some cases, there are combinations of grooves with cuttings, notches, and pits. A small group of rims do not have ornamentation at all.

Walls of the vessels are decorated with various pinholes and pits, thin and slightly curved comb prints, notches, and incised lines. Deviate pins made by sticks and different kinds of pits are rarer. Specific combinations of elements include prints of bidental stamp and slightly recessed pits, notches and vertical zones of small pins, crossed comb impressions, and pins made by broken stick, oblique pinholes and prints of slightly inclined stick, comb prints, and deep pinholes, pinholes and incised lines.

The described elements are usually organised within horizontal zones. Less common are vertical, oblique or criss-crossed motifs. More than half of the ceramic fragments from the Asaviec 4 settlement are not decorated.

Flint artefacts are not numerous (Figure 3: 1–8). There are three leaf-shaped arrowheads, made from fairly regular blades. They have shafts formed by dorsal abrupt retouch and clear wedge-shaped points. Their morphology is very close to the arrowheads of the Mesolithic Kunda culture. Spear heads are leaf-shaped and bifacial. Most of the scrapers are end-type items formed on regular blades. Some tools are formed on shorter blades, flakes, and chunks. Burins are represented by singular angular items on flakes. Other flint tools include rare perforators and scrolls, cutting tools on regular blades with flat retouch. Several flakes have a small edge retouch and could be used for cutting and scraping. There are asymmetric axes of adz-shape. There are few nucleuses, which are small and tired out. One trapeze with a fine edge retouch was found.

Bone and antler artefacts (Figure 3: 9–20) include two short needle-shaped biconical-like arrowheads, and one needle-shaped arrowhead that is flattened and has slightly extended shaft. Several artefacts with round crossings and cylindrical fragments could also be recognised as parts of arrowheads. There are two fragments of points with a flat rhombic section, one of which has jagged notches on one edge. Moreover, there are two fragments of harpoon heads and quite a lot of fragments of flat daggers. Tools made from split tusks of wild boars and burin made from bear tusk can be attributed to a separate group. Perforators were mainly made from split tubular bones. Axes and adzes made from antler and tubular bones are represented by broken fragments. The only exception for axes is an antler item with a slightly asymmetrical blade.

Adornments are presented by one unharmed and one broken pendant from teeth of the animals with a circular groove on the root (Figure 3: 13).

To date, Asaviec 4 is the only known early Neolithic site in the Kryvina peat bog. It is dated by 5th–2nd half of the 4th millennium BC (Чернявский

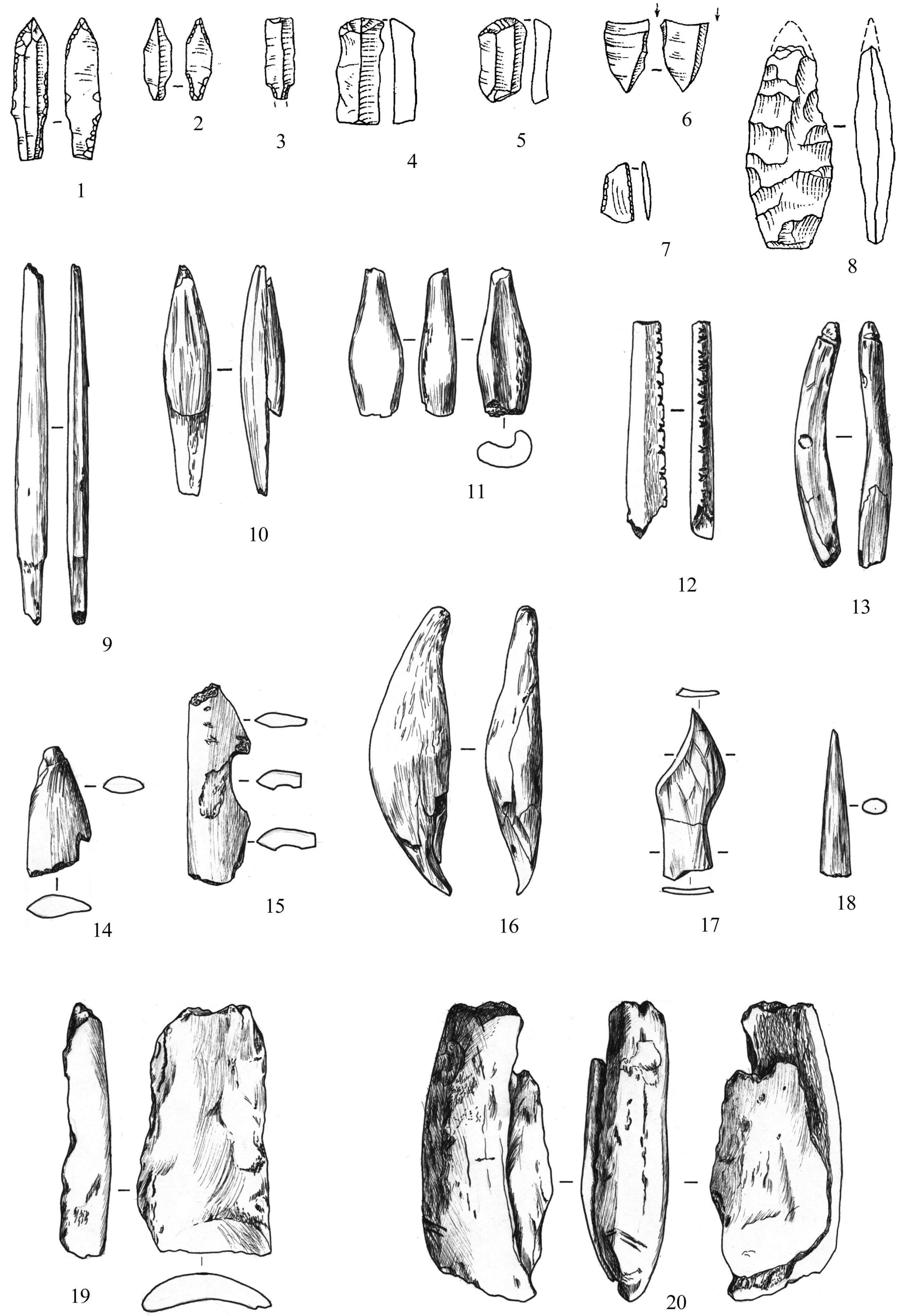

Figure 3: Asaviec 4 settlement. Flint and bone artefacts of the Narva culture. 1–3, 9–12 – arrowheads; 4, 5 – scrapers; 6, 16 – burings; 7 – trapezes; 8 – spear head; 13 – pendant; 14, 15 – harpoon head; 17 – cutting tool; 19 – adze; 20 axe. From the materials of Michal Charniauski.

2012, p. 96). The oldest ^{14}C date for it is 5860±50 BP (K-6213) (4800–4620 cal BC). With the heavy regression during the transition from the Atlantic to the Sub-Boreal phase, the water level decreased approximately 3 m below the modern level (Зубович 2004, таб. 1). As a result, another shoreline was formed at a distance of about 500–600 m from the Asaviec 4 settlement. The inhabitants of this settlement had to leave it due to the regression that occurred at the end of the 4th millennium BC (Чернявский 2012, p. 96).

Later on, two new settlements Asaviec 2 and Asaviec 5 were founded in the northern part of the Kryvina peat bog and the Kryvina 1 and Kryvina 2 sites in the southern part of the region. Few fragments of pottery of the Narva culture were found on the natural soil of the Asaviec 2 settlement (Charniauski and Charniauski 2010, p. 108). However, the location of the Early Neolithic sites in the southern part of the peat bog remains unknown.

Kryvina Peat bog during the end of the 4th–3rd millennium BC

Soon after the appearance of these new settlements, a wave of cultural transformation occurred, caused by the penetration of the bearers of the Comb-Pit Ware culture in the Belarusian Lakeland from the North. As a result, Usviaty Middle Neolithic culture appeared in the region (end of the 4th to middle of the 3rd millennium BC) (Чернявский 2012, pp. 92–94). Its materials were found in the lower part of the cultural layers of the Asaviec 2, Asaviec 5, Kryvina 1, and Kryvina 2 settlements. All of them are peat bog sites and therefore retain a large number of organic artefacts.

The most frequent material of the Usviaty culture at the settlements is pottery (Figure 4), featuring mainly fragments of widely opened kettle- and helmet-shaped pots with slightly blunted sharp bottoms. Fragments of bowls, including oval, and tiny vessels are rarer finds. The rims of the pots have thickened and beveled inside edges. Straight, rounded or thickened rims are rarer. Vessels were made from coils, which were joined to one another by 'U' type connection. Joints were covered with an additional layer of clay. The surfaces of the vessels are very thoroughly worked out with the technique of beating. Some fragments bear traces of polishing. There are also fragments with traces of rolling on the surface of a braided stick. Paste was tempered predominantly by crashed shells, in some cases with tiny organic particles and fired clay. Ornamentation is mainly characterised by the medium and large size of elements and its sparseness. Notches, various pinholes, and side prints of braided stick (known as larva stamps) are the most characteristic elements. Scored thin lines are less common. Comb prints were very seldom used. Ornament usually forms sparse horizontal zones. Sometimes they are more dense and dual. Elements are often slanted to the right, whereby occasionally they form a zigzag, horizontal 'fishbone' pattern, and rhombic figures. Sometimes there are complicated patterns such as images of snakes, birds, symbols and signs of unknown meaning (Charniauski and Charniauski 2010, pp. 104, 108). Ornamentation frequently covers the walls, bottoms, and rims. Edges of the rims and the upper inner surface of the pots could also be decorated.

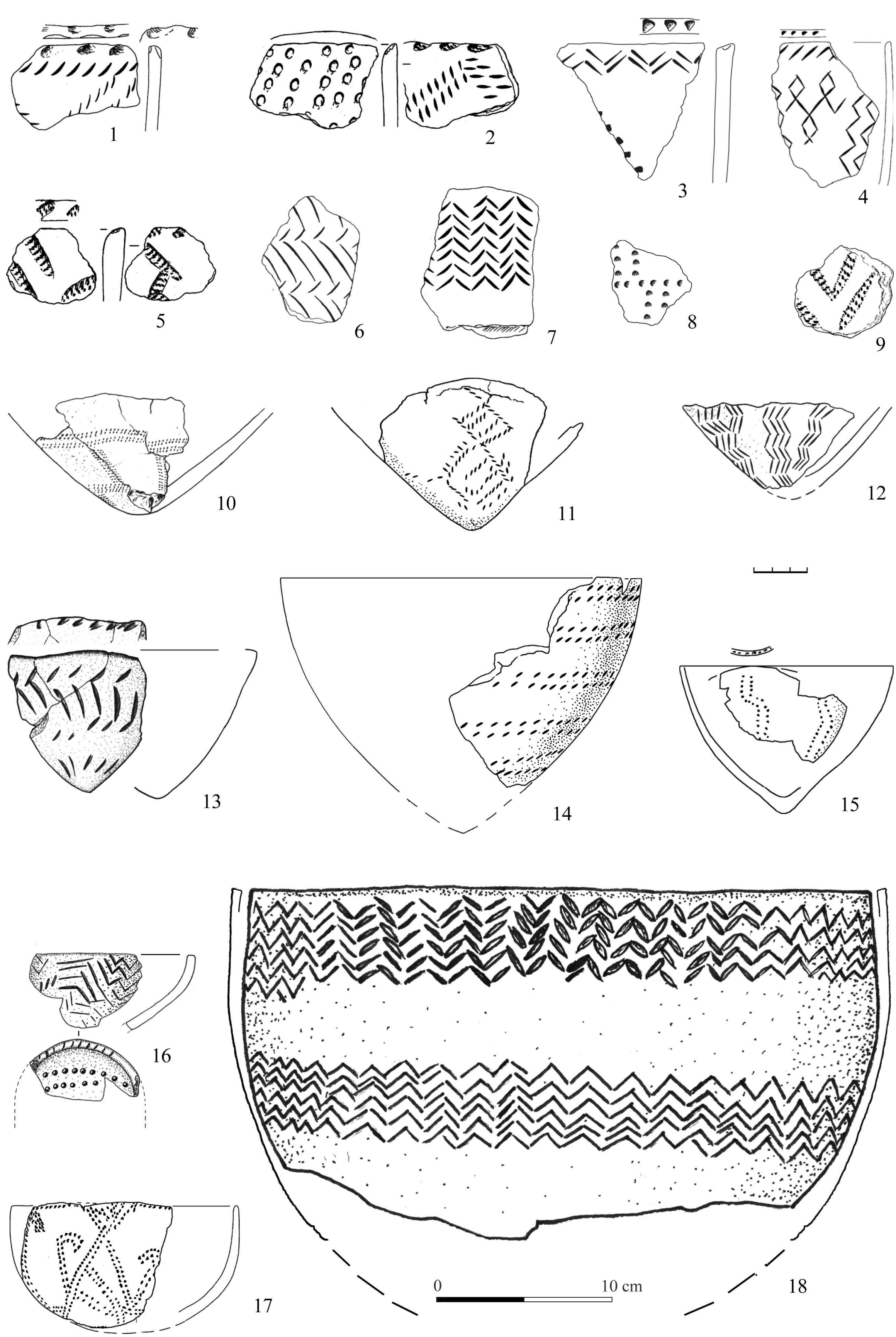

Figure 4: Asaviec 2 settlement. Pottery of the Usviaty culture. 1–12, 14, 15, 17 – according Michal Charniauski.

Scrapers and cutting tools dominate in flint collections of the Usviaty culture from the settlements of the Kryvina peat bog. There are leaf-shaped, drop-shaped, and rhombic arrowheads, and a small number of javelin heads. Stone tools are represented by hummer stones, rubbing stones, and rare foreshaft, rounded section axes.

Bone and antler artefacts include perforators, arrowheads with flat shafts, spear heads made from massive tubular bones, knives, cutting tools made from split wild boar tusks, chisels, axes, and adzes, stamps for ornamentation of ceramics, etc. (Чарняўскі 2007, pp. 58–59). A small number of tools, household articles, and arrowheads contain grooved ornamentation on the surface.

Wooden artefacts are quite rare, mainly being fragments of houseware. One wooden arrowhead — whose morphology is similar to bones items — was found (Чарняўскі 2013, p. 320).

Adornments are presented by pendants made from perforated animal teeth and beads from tubular bird bones. Bearers of the Usviaty culture started to make amber beads and pendants with frontal perforations from imported raw material.

Starting from the beginning of the 3rd millennium BC, new cultural influences began to penetrate into the region. The earliest of them was a Globular Amphora culture. Fragments of amphora of this culture were found at the Asaviec 2 settlement (Charniauski and Charniauski 2010, p. 108). Influences of the Corded Ware Ceramic tradition can be more clearly traced and dated by 2930–2460 cal BC. They were probably penetrating into the central and eastern parts of the Belarusian Lakeland from the North through the Dzvina (Daugava) River and its tributaries.

Archaeological materials of the Circle of Corded Ware Ceramic cultures are mainly represented by pottery fragments (Figure 5: 9). These vessels were made from paste tempered by sand and small crushed rock. The inner and outer surfaces are covered with irregular linear traces left by a tuft of grass mainly in a horizontal direction. Corded prints, smooth stamp impressions and cutting elements are typical for ornamentation. The most common motive is a horizontal 'fishbone' pattern. Triangle arrowheads with bent-inward and flat bases found in late Usviatian layers also belong to the Corded Ware traditions (Figure 6: 1–4).

At the end of the first half of the 3rd millennium BC, new influences forced a transformation of the Usviaty culture into the Northernbelarusian culture (Zhyzhyca-Kryvina stage) (Charniauski 2016; Чернявский 2014). At the beginning of this new culture existence, its bearers continued to live in the Asaviec 2, Asaviec 5, Kryvina 1, and Kryvina 2 settlements.

Ceramics of the Northernbelarusian culture (Zhyzhyca-Kryvina stage) is presented by pots, beakers, bowls, and tiny vessels (Figure 5: 1–4, 10–13). At the beginning of the culture, the vessels were with bluntly sharp and rounded bottoms. Shortly afterwards, all vessels became purely flat-bottomed. Flanges and trays as elements of flat bottoms can be also traced. The rims are slightly bent or straight, being more rarely slightly turned in. Their edges are normally rounded or flat. Pottery was made by different paste recipes. At the beginning of the Zhyzhyca-Kryvina stage, pottery was made from the same paste recipe tempered by crushed shells, fine organics, and fired clay as pottery of the Usviaty culture. Cut of grass and avian feathers (bird lime?) were used as temper material

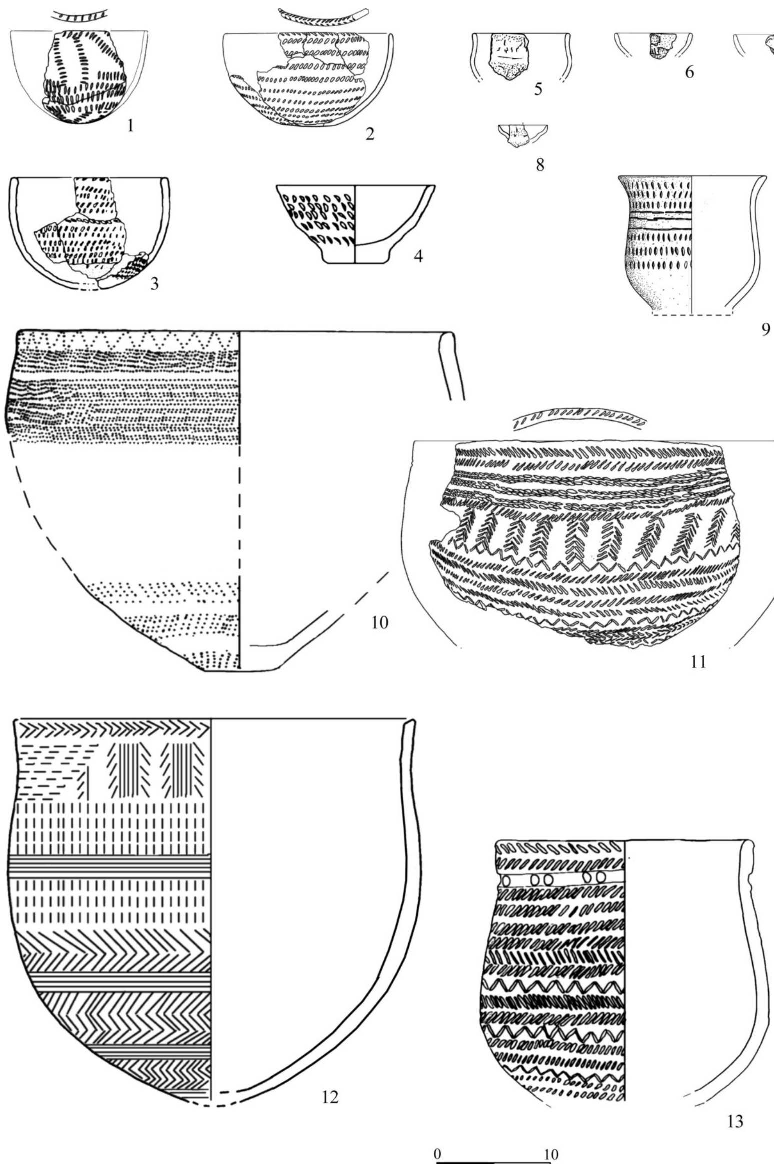

Figure 5: Pottery of the Northernbelarusian culture (1–8, 10–13) and of the circle of Corded Ware (9) cultures. 1–2, 5–9 Asaviec 2 settlement; 3,4,10–13 Asaviec 7 settlement.

later on. New admixture — sand — appeared at the middle of this cultural stage evolution, while crashed shells gradually disappeared. Pottery tempered by minerals (sand and small gravel) dominated at the end of the Zhyzhyca-Kryvina stage.

The vessels were formed from coils, which were joined to one another by "N" type connection. Only at the beginning of the culture hybrid 'U' type / 'N' type techniques were used. Both surfaces of the vessels are covered with irregular linear traces left by a tuft of grass mainly in a horizontal direction. Furthermore, a particular ceramic group can be distinguished with a surface treated with two techniques, namely smoothing the surface with the "hammer and anvil technique", followed by subtle and partial crosshatching also with a tuft of grass.

Pots of the Northernbelarusian culture (Zhyzhyca-Kryvina stage) are often large, with a diameter about 30–40 cm. Tiny vessels — which copy the morphology of the large items — could be up to 5 cm in diameter. The

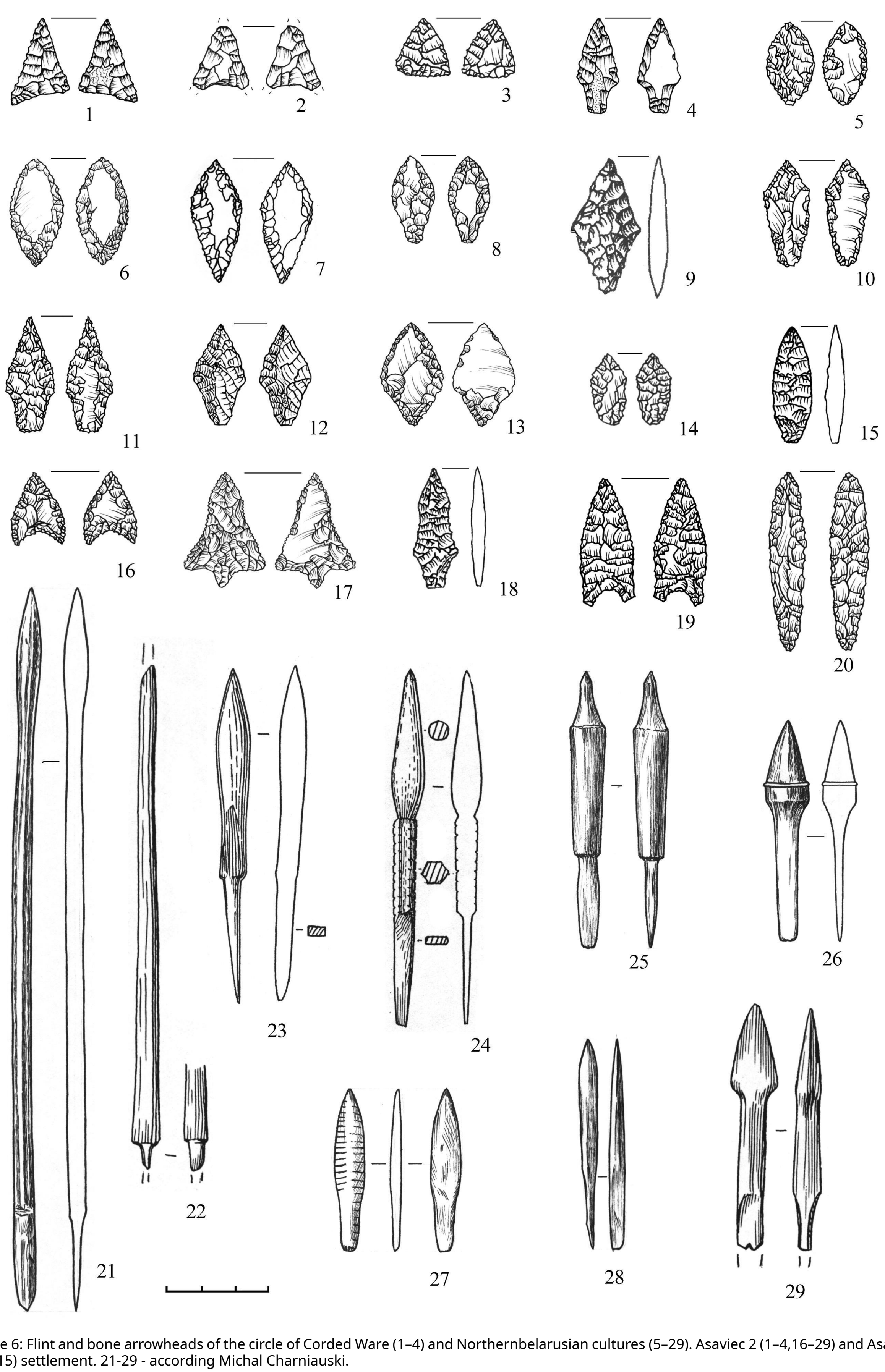

Figure 6: Flint and bone arrowheads of the circle of Corded Ware (1–4) and Northernbelarusian cultures (5–29). Asaviec 2 (1–4,16–29) and Asaviec 7 (5–15) settlement. 21-29 - according Michal Charniauski.

most common ceramic forms are widely opened helmet-shaped, biconical truncated with a transition in the upper third of the pots, and with a slight S-shaped profile (Charniauski and Kryvaltsevich 2011, pp. 118–119). The forms of beakers and bowls are quite simple, although some beakers have a slightly S-shaped profile.

Decoration of the Northernbelarusian culture's pottery is denser than in the Usviaty culture. Typically, ornamentation covers the whole vessel, including the bottom and rims' edge. The inner surface of the pot's rim is also quite often decorated. The inner surfaces of flat bottoms of some of the vessels are also decorated.

Different prints of a smooth stamp, more rarely a comb stamp, straight and curved notches of various length, cord prints, round, oval and amorphous pits (with smooth or irregular bottoms) are the main elements of the ornamentation. Traced lines by a thin or wide stamp or by wooden stick are also represented.

The most typical motifs of the ornament are 'fishbone' horizontal, horizontal rows of vertical or inclined prints, wide and relatively deep circular grooves under the rim with single or double pits, oblique rows of straight, inclined or horizontal prints, and single or double horizontal zigzags. Corded prints and streaked ornaments — including dashed triangles — are quite seldom among the total number of pottery fragments (less than 1 per cent).

The absolute majority of flint, bone, and antler tools types of the Northernbelarusian culture (Zhyzhyca-Kryvina stage) are similar to the previous Usviatian tradition. Changes are only seen in adornments and ritual articles, and a small number of new types of flint and bone arrowheads. New types of bone tools were preformed primarily for flint working, woodworking, and household work (Чарняўскі 2007, p. 60).

The variety of flint raw materials significantly increased due to the established connections of the Northernbelarusian culture with the territories of the Corded Ware culture traditions. There are flints from the Vilija, Sozh, and Nioman regions besides low-quality local raw materials. The collections of flint tools are quite diversified, with the majority of artefacts made on flakes. A variety of scrapers and combined tools with one or more scraping edges dominate in the collection. The trapezoidal with end or with double-sided and end fronts, and narrow elongated scrapers with a high-scraping front along the perimeter are the most distinct types of scrapers. The second most numerous class of flint items is arrowheads (Figure 6: 1–20). For the Northernbelarusian layers of the Asaviec 2 and Asaviec 7 settlements, their number is very high. On average, there are 1.3 arrowheads per m^2 (Чарняўскі 2010, p. 197). Leaf-shaped and rhombic types with or without shafts are most numerous among the arrowheads. They are identical to the artefacts of the previous Usviaty culture. New cultural influences are represented by an elongated rhombic with a shaft, a triangle with bent-inward or flat bases, a symmetrical rhombic with a narrowed point and shaft, willow-leaved with short shaft arrowheads. There is a group of flint arrowheads that copies the morphology of one of the most numerous local types of bone points (Figure 6: 18). Other flint artefacts are represented by javelin and spear heads, axes, cutting tools, perforators, drill heads, chisels, retouched blades, and flakes. There are many combined tools of multiple uses.

The lack of flint raw materials of good quality led to their maximum usage. For example, finds of unharmed polished flint axes are quite rare, and they were all imported. At the same time, a certain number of small tools such as arrowheads, scrapers, blades, and flakes with retouch have polished areas on their surfaces. There is a certain quantity of middle or rear parts of broken polished axes, too. Both observations could be interpreted as indications of the re-use of broken axes. The lack of flint could also explain the quantity of combined tools.

Stone tools of the Northernbelarusian culture are presented by singular socked and drilled axes and their fragments, rubbing stones, net sinkers, polishing plates, and tiny chisels.

The collection of bone and antler tools is represented by more than twenty types (Чарняўскі 2007, pp. 59–60), including arrowheads (Figure 6: 21–29), spear heads, daggers, harpoon heads, U-shaped fishhooks, and large hooks, pegs (small needle-shaped articles), axes made from unharmed and split fragments of horn's tines, adzes, chisels, shovels, punches, squeezers, retouchers, palette-knives, pottery stamps, "fish" knives, spoons, hafts, small triangular articles with a flattened section, thrust tools made from horn remains, articles made from elk horns with a remaining appendix, and a part of horn blade.

Layers of the Northernbelarusian culture contain artefacts made from wood and bark, namely net's buoys, fragments of different houseware, and fish traps.

The Northernbelarusian culture (Zhyzhyca-Kryvina stage) is the first culture of the Belarusian Lakeland where metal artefacts appeared (Чарняўскі 2006). In the Asaviec 2 and Asaviec 7 settlements, three copper and bronze perforators and two indeterminate fragments were found.

Adornments and ritual items are quite numerous (Figure 7; Чарняўскі 2015). Bone items are presented by pendants made from mammal and fish teeth, simple, flat-shaped, and key-shaped, from untreated bones, anthropomorphic, and zoomorphic one, beads, and uncertain fragments. Wooden items are presented by a baton with anthropomorphic figurine made on its extremity (Чарняўскі 2015, p. 246). Clay items are presented by a small series of tiny spheres (approximately 1 cm in diameter, some of which have nail prints), one small damaged ornithomorphic sculpture and a split along an ornamented cylinder (Чарняўскі 2015, pp. 246–8). Amber pendants and beads — among the most impressive of the adornments and religion items (Charniauski 2001) — were imported from the Baltic region to Kryvina peat bog settlements in finished form. They differ from previous adornments of the Usviaty culture through their higher level of elaboration, regular geometrical forms, and cross holes. The earliest musical instruments are presented by flutes made from tubular bones of birds (Figure 7: 17).

During the Zhyzhyca-Kryvina stage of the Northernbelarusian culture, certain changes in settlement distribution took place. The favourable living environment and advanced methods of gathering — including high reserves of water nuts — led to an increase in the size of the existing Asaviec 2, Kryvina 1, and Kryvina 2 settlements as well as establishing new ones, namely Asaviec 1, Asaviec 7, and Kryvina 3. All new settlements

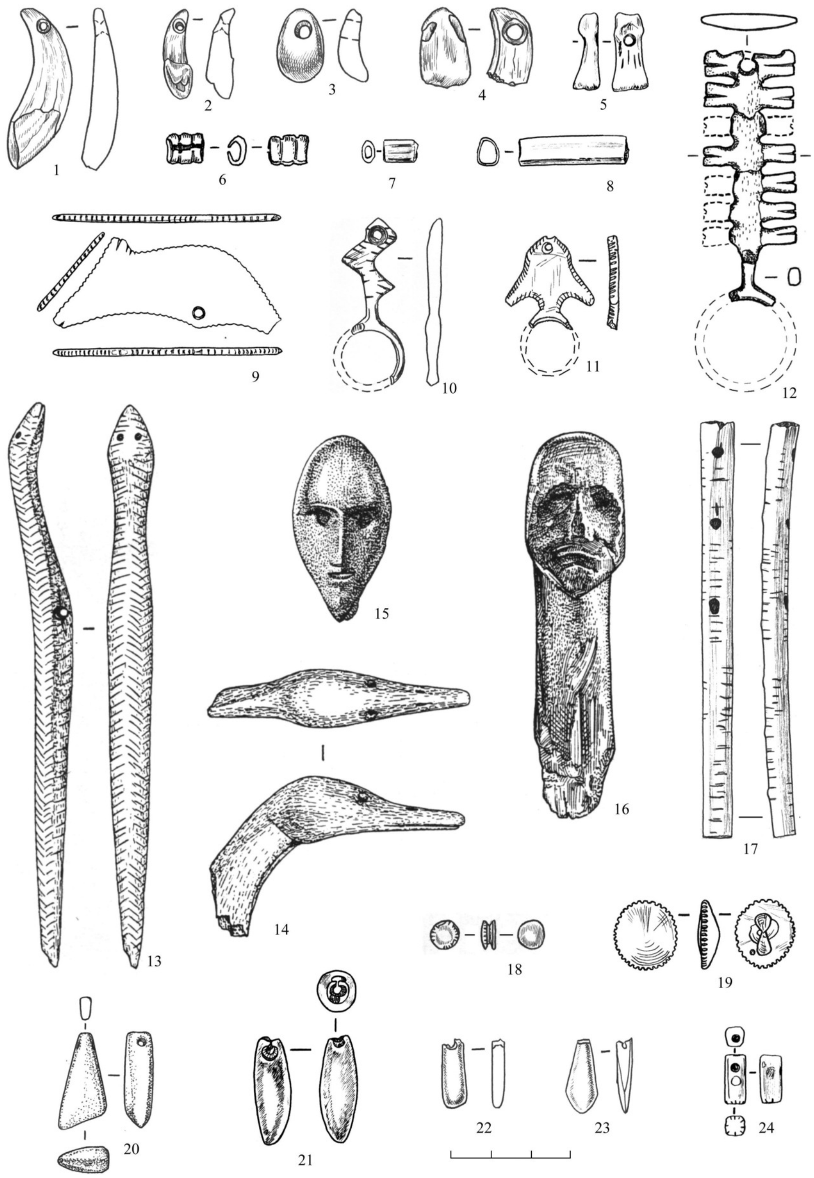

Figure 7: Adornments and religious items, musical instruments of Northernbelarusian culture. 1–3, 7, 8, 13–16, 18, 22, 23 – Asaviec 2 settlement; 4–6, 9–12, 17, 19–21, 24 – Asaviec 7 settlement; 1–11, 13–15, 17 – bone; 12 – antler; 16 – wood; 18–24 – amber. 13-16 - according Michal Charniauski.

were established on new dried turf shores of the paleolake after its regression phase at the end of the 3^{rd} millennium BC. All previous existing settlements were also slowly moved afterwards.

The long period of transgression began in the middle of the 2^{nd} millennium BC. The gradual increase of the lake surface initially forced the inhabitants of Asaviec 7, Asaviec 1, and Kryvina 3 settlements and later of Asaviec 2, Kryvina 1, and Kryvina 2 settlements to leave their places. A new settlement Asaviec 3 was established in the northern part of the peat bog. Materials of this time are known at the Asaviec 5 settlement and on the hill near the Early Neolithic Asaviec 4 settlement (Asaviec 4a location). During this time, mineral temper dominated in the pottery paste of the Northernbelarusian culture. Beaded ornaments seldom appeared among ornamentation motifs.

Ancient inhabitants of the peat settlements left the southern part and moved to the main shore of the nowadays peat bog, although sites of this time remain unknown there.

Materials dated by the second half of the 2nd millennium BC were found at the Asaviec 3 and Asaviec 6 sites, albeit only a small part was excavated.

Conclusion

The Kryvina peat bog is a unique archaeological region, whose territory was inhabited for almost 4,000 years. Archaeological materials of the settlements allowed us to trace the development and transformation of the Early Neolithic Narva culture, the Middle Neolithic Usviaty culture, and the Late Neolithic–Early Bronze Age Northernbelarusian culture. The peculiarities of the cultural layers of the settlements allowed tracing in detail changes in household, hunting, fishing, and gathering through the evolution of these cultures. Changes in the quantity and localisation of settlements according to the variability of climate conditions show the level of adaptation of the prehistoric local population to the environment. Cultural and chronological reconstructions based on materials of the Kryvina peat bog reflect the overall processes that occurred in the Belarusian Lakeland during the Neolithic–Bronze Age time.

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Neolithic wetland and lakeside settlements in the Balkans

7

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The Neolithic archaeology in the Balkans witnesses momentous step forward in the research of first farming communities inhabiting this region. In comparison to previous period of examination focused on the determination of archaeological sites and material culture, the last few decades provide a novel approach in multidisciplinary studies and more thorough understanding of Neolithic societies. Many new specialists appear, international collaboration is more frequent and numerous publications, conferences, and workshops are produced that have an effect on the improvement of methods and knowledge employed within prehistoric archaeology. Consequently the major issues in the Neolithic archaeology are reconsidered and strengthened with new data in regard to archaeological science and theory. But, in spite of these advantages, not much was done in the sphere of wetland archaeology. There are a number of Neolithic sites excavated on marshy valleys and lakeshores, but they were not observed in terms of wetland archaeology. And their number is not small if the potential of data is concerned.

Therefore this paper will consider the Neolithic pile dwellings and tells in the Balkan marshes and lakes that are excavated so far, but not incorporated within wetland archaeology. Many of them remain unknown to majority of European archaeologists due to modest publications mainly in local languages, but also partly due to their absence in the most distinctive research, overviews, and handbooks of wetland archaeology. The pivotal focus of wetland archaeology on pile dwellings and omission of other 'dryland' sites established in marshy areas also has an effect in scarce presence and concernment of Balkan settlements in the major publications of this archaeological discipline. Consequently, this paper will concern both wetland and 'dryland' sites in the Balkan Peninsula and propose their networks and geoarchaeological research as further direction of study in the wetland archaeology. It is an attempt to summarise the current knowledge on pile dwellings and tells in waterlogged areas and to put it forward for the future research that can significantly contribute in thorough understanding of Neolithic lakeside and wetland settlements and their environment.

Wetland archaeology in the Balkans

For more than a century wetland archaeology has been part of European methodology, theory, and museology. Even before the Ferdinand Keller's first excavation of lakeside settlement in 1854 there were explorations of wetland sites, but the actual *Pfahlbaufieber* and the creation of artificial *Pfahlbaukultur* took place in the second half of 19th century (Menotti 2012). It seems that the *lake-dwelling rush* does not reach the Balkans as it had effect in Central and Western Europe. The region of Southeast Europe was still not aware of it even when the wetland studies progressed into processual archaeology. Many propose political circumstances and

Naumov, G. (2020). 'Neolithic wetland and lakeside settlements in the Balkans'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 111–135. DOI: 10.11588/propylaeum.714

geographical conditions as main factors for the absence of wetland archaeology in the Balkans, but as current studies will demonstrate neither politics nor quantity and quality of sites was the cause. The archaeology of Southeast Europe was open to western methodology before and after the World War II (Novaković 2011), and its ecosystem provided environment for numerous prehistoric pile-dwellings. It is worth to note that there were few observations of such sites, but even then they were sometimes not confirmed as prehistoric settlements, but as fishing systems and docks (Koco 1951; Mikov 1950; H. Škorpil and K. Škorpil 1921).

Although the potential prehistoric pile-dwellings were indicated earlier, the first Neolithic wetland sites in the Balkans were excavated after the World War II. Some of these sites were explored largely in 1960's and 1970's and several are initially excavated recently. Majority was considered as dryland settlements without significant consideration of geoarchaeological survey, while those excavated on lakesides were not given larger attention. In many overviews on the Balkan Neolithic and the prehistory in general there is no concern to these sites, or were just mentioned as isolated feature without emphasis on their specific character (Bailey 2000; Benac 1979; Korkuti 1995; Perlès 2001; Todorova and Vaisov 1993). This could be a result of misapprehension of the wetland archaeology as separate component within the archaeological discipline and more understood as something that is integral to diverse methodology and ecosystem. Even in some of the substantial studies and handbooks on European and World wetland archaeology there is nothing on its counterparts from the Balkans, or few were included only in a line or two (Menotti 2004, 2012; Menotti and O'Sullivan 2013). Such unpleasant state with the absence of Balkan wetland archaeology could be a result of several factors. Majority of wetland and lakeside sites were not extensively published and there is not much information about them, or they are involved only in publications in local languages that were also not accessible to western authors. But even in the case of more local overviews, these sites were not particularly concerned. This could be due to deficiency of wetland archaeology as concept in Southeast Europe and therefore consideration of these sites as uncommon or as something that could not be studied with usual archaeological methods.

The 'absence' of wetland sites in the Balkans is not due to its geography and inadequacy of its landscape, as it was proposed before. Besides the scarcity of published reports or monographs associated with these settlements, there was not a particular interest in lacustrine and marshy areas that could be also a result of deficit of equipment and the necessity of more complex methodology, logistics, and the infrastructure essential for excavation of such sites and study of organic material. The underwater archaeology is not unknown field in the Balkans, but it is mainly applied on Classical sites, and extremely rarely on prehistoric (Bekić 2009; Georgiev et al. 1991; Peev 2008). Even in the case of prehistory, these sites belong to Bronze and Iron Age (Angelova and Draganov 1995; Kuzman 2013; Naumov et al. 2018a; Todoroska 2009), while none of the Neolithic is excavated with these methods so far, or it is not published yet. Consequently, the majority of lakeside Neolithic sites were preferably explored in terms of 'standard' archaeology and in seasons that provided approach for research of such areas.

In terms of wetland archaeology in the Balkans it should be asserted that until a decade ago wetlands were not considered as particular feature in the Neolithic landscape. As result to intensive drainage of smaller lakes and marshes in 1950's and 1960's, many of sites in the vicinity of waterlogged areas were preserved in changed environment and therefore considered as dryland settlements. Nevertheless, some of the previous and recent studies indicate that these marshy lakes were significant factor in establishing social, economic, and symbolic relationship with the wetland landscape (Alexakis et al. 2009; Commenge 2009; Kitanoski et al. 1980; Naumov 2016c; Tripković et al. 2013). The structures of the settlements in wetland valleys were apparently different than that of pile-dwellings, but they do not comprise diverse social basis uncommon for the Neolithic. Although often considered as dissimilar social units and observed separately in so-called dryland and wetland archaeology they shared the major Neolithic features and modes of identity manifestation. Such wetland sites established as tells in the Balkans were never incorporated within wetland archaeology, perhaps due to the scarcity of wooden material and the absence of surrounding water in the excavation seasons.

Nevertheless, the latest research makes emphasis on dried marshes and lakes and gradually contributes these sites in terms of wetland archaeology (Alexakis et al. 2009; Fouache et al. 2010; Naumov 2016a). As result to that it is evident that there are two major features of settlements founded in waterlogged areas i.e. wetland and lakeside villages. In regard to the environment they adjusted its architecture, so that tells were common for wetlands and pile dwellings for those erected in the vicinity of lakes. But with the exception of architecture their material culture was notably similar and integrated in synchronous social processes. Moreover these seemingly different settlements were solidly networked and sometimes shared their identities through trade, rituals and visual culture (Benac 1979; Chrysostomou et al. 2015; Naumov 2016b). Therefore in this paper, they will be presented simultaneously as two components of wetland archaeology and in such way they will contribute in better understanding of communities living next or within marshes and lakes. In addition their mutual relationship will be emphasised in order to propose new avenues of research in wetland archaeology.

Lakeside settlements

The lakeside settlements are distinct phenomenon in the wetland archaeology and as such in the Balkan archaeology as well (Figure 1). Due to their apparent features i.e. pilled houses, platforms, palisades, trackways, and artifacts made of wood, they are considered as different category in the prehistoric architecture and spatial organisation. Although recently studied more frequently, their quantity is still small, especially if compared to those in Circum-Alpine region (Hafner et al. 2014; Schlichtherle 1997; Velušček 2006). Current research indicates that there are potentials for many new sites, so that the geographical factor is definitely excluded for their scarce presence in the Balkan archaeology. This region is familiar for its mountains, but there are also numerous lakes in their vicinity or in the valleys that could be prospective locations for pile-dwellings. Surely, drier climate in the Balkans than that of Circum-Alpine region is a factor for less preservation of prehistoric wooden remains and therefore their number is evidently smaller. But the lakeside areas, as well as marshy valleys, were never thoroughly surveyed, so potentials for wooden structures remain

Figure 1: Map of the Balkan Peninsula with the location of Neolithic pile-dwellings. Greece: 1. Dispilio, 2. Amindeon region — Limnochori II, Limnochori III, Anarghiri III, Anarghiri IXa and Anarghiri IXb; Albania: 3. Maliq, 4. Dunavec, 5. Sovjan; North Macedonia: 6. Ohridati, 7. Ustie na Drim, 8. Crkveni Livadi; Bulgaria: 9. Lake Varna; Bosnia: 10. Rudarska Ulica, 11. Gornja Tuzla; Croatia: 12. Zambratija.

unknown. As some of the recent excavations confirm, the pile-dwellings can be found a bit far from the current lakeshore and consequently some new could be expected in such areas (Chrysostomou et al. 2015; Kuzman 2013). Also some of the sites that were found on the lakeshores of these lakes belong to later prehistory and imply the possibility for the Neolithic settlements to be found in future.

In regard to the chronology of lakeside settlements in the Balkans it should be accented that there are no recorded sites that could be attributed to the Mesolithic. Although there is vast waterlogged archaeological evidence for the Mesolithic of Scandinavia, the Baltic and Britain (Menotti 2012; Van de Noort and O'Sullivan 2006), still there is no confirmation to synchronous pile-dwellings in the Balkans, besides the abundance of sites from this period. Neither Early Neolithic lakeside settlements with wooden constructions are unearthed so far as it seems that the process of Neolithisation was directed rather towards fertile flatlands and on the slopes of hills or mountains than on the lakeshores. The earliest so far pile-dwellings are dated in the Middle Neolithic while its quantity largely increase in the Late Neolithic. The tradition of establishing wooden buildings on the Balkan lakeshores continued in the Chalcolithic, Bronze Age, and Iron Age, but these sites will be out of focus in this paper (Angelova and Draganov 1995; Chourmouziadis 2002; Kuzman 2013; Naumov et al. 2019, 2018a; Rujak 2014; Todoroska 2009).

In order to have a more detailed insight into the lakeside settlements a regional overview will be disposed based on the level and number of research in each of the states incorporated within the Balkan Peninsula. Although Slovenia in terms of prehistory is sometimes geographically considered as part of this region, it will not be included in this overview due to solid presentation in the wetland archeology and its close relationship with settlements from Circum-Alpine area (Velušček 2006). On the other hand, Greece is occasionally not incorporated within the Balkans, but as there are evident resemblances with corresponding sites in Albania and North Macedonia it will be listed as well. In fact, most of the data and knowledge on lakeside settlements in the Balkan Peninsula comes from research in Greece and therefore significantly contribute in the understanding of formation processes, spatial organisation, and material culture associated with communities inhabiting these specific villages made of wooden buildings. The present overview will consist of current data available for the lakeside settlements in the Balkans although many sites lack reports or more elaborated publications. At the current state the available information is still modest, but it enables initial comprehension of the pile-dwelling societies in this region.

Greece

One of the earliest studies of lakeside settlements in the Balkan Peninsula was in Greece on now renowned site of Dispilio at Lake Orestia (Figure 2). The site was discovered in 1932 and small scale excavation were performed, while in 1970's and 1990's more extensive recording of piles and systematic excavation started (Hourmouziadis 1996; Theodoulou 2011). Since then numerous archaeological seasons were performed and they are still going on in more advanced multidisciplinary direction (Chourmouziadis 2002; Kotsakis 2006). The excavation provided abundance of data for this site and enabled reconstruction of chronology, economy,

Figure 2: Photo of Dispilio pile dwelling in 1930's (Facorellis et al. 2014, Fig. 1).

diet, crafts, and architecture. The inhabitants of this settlement were living in pile dwellings on the lakeshore, but also in houses made of clay established on nearby dryland. In various eras the site was changing its structure according to changes of lake levels which gradually made deposit suitable for building of houses on dry ground (Karkanas et al. 2011). These environmental changes and radiocarbon dating imply that Dispilio was a dynamic settlement that fluctuated both socially and economically.

The published radiocarbon analysis confirms that site's earliest occupation was at 5355±125 BC i.e. Middle Neolithic and was continuously active until 3644±118 BC. It was abandoned in period between 3520 and 2460 BC and shortly reoccupied from 2300±160 until 2129±152 BC (Facorellis et al. 2014). In terms of Southeast European chronology, the settlement was established at the end of Middle Neolithic, most dynamic in the Late Neolithic and abandoned in the Chalcolithic. Radiocarbon dates indicate that it was shortly reoccupied in the Bronze Age, while some of surrounding surface material suggests inhabitation of this area even in the Early Neolithic, but none of the dated wooden constructions confirms this yet (Perlès 2001; Theocharis 1973). The nearly 2000 years of the site engagement provided numerous archaeological, geological, zooarchaeological, and archaeobotanic information and thus thorough evidence for the prehistoric communities that lived there.

The spatial analysis of wooden material indicates that there was area densely inhabited and also had open spaces, although discussions of massive platforms and surrounding palisades are still on (Touloumis and Hourmouziadi 2003). Besides pile dwellings, also mudbrick and daub structures were built on areas where the lake level was lower, so in the initial period the settlement was consisted of only palafittes while from the Late Neolithic to Bronze Age there was combination of piled and daub houses (Karkanas et al. 2011). The inhabited dry area was majorly used for processing of food and wooden structures for fishing, although zoological and botanical data suggests that the society was mostly focused on agriculture and stockbreeding, and was not specialised on fishing. On the other hand, the well made fishing tools demonstrate the developed provision of food from the lake and especially at the earlier stages of settlement when bigger spears were made for larger fishes. The food, besides fish, was consisted of einkorn and emmer wheat, barley, lentils, ovicaprides, pigs, cattle, and hunted red deer, roe deer, and boar perhaps for provision of raw material for tools and ornaments (Touloumis and Hourmouziadi 2003). There is also abundance or ceramic finds and stone tools that illustrate the dynamic social, economic, and ritual life at Dispilio in regard to networks that were established with number of sites in the region.

The continuous excavation at Dispilio will furthermore contribute in better understanding of lakeside settlements and communities that dwelled within, but a broader scope of such sites is necessary in order to consider varieties or uniformity of villages established next or onto lakes. In spite of hundreds of Neolithic sites in Greece, of which many gave crucial information on the process of Neolithisation, there are not many pile-dwellings. This could be mainly due to the invisibility of these sites in now dried environment and deposited geological layers, although, in spite of wetlands, the lake areas could still evidence the Neolithic remains. One of such areas is the Amindeon region of four lakes (Petron, Vegoridis, Zazari, and Chiamaditis). The ongoing extensive excavation which started approximately 15 years ago provide the momentous data on several pile-dwellings and the most comprehensive information at the moment for any of the lakeside settlements in Southeast Europe. Approximately 40 Neolithic sites were determined of which dozens were pile-dwellings dated in the Middle Neolithic at earliest (Chrysostomou and Giagkoulis 2018; Chrysostomou et al. 2015; Touloumis and Hourmouziadi 2003)[1] .

1: More on the recent research on pile-dwellings in Amindeon region in Chapter 8 of this publication.

Among many significant unearthed sites few are exceptionally distinct due to the abundance of wooden and daub structures, as well as because of the numerous specific ceramic, stone, and bone finds. Most of them are dated in the Late Neolithic i.e. phases I and II, and the Final Neolithic (equivalent to the Balkan Chalcolithic), while some had continuous occupation in the Bronze Age and Iron Age. Anarghiri IXa and Limnochori II are the earliest dated pile dwelling sites (5500-3200) and few others appear in the beginning of 5th millennium or in its second half (Chrysostomou and Giagkoulis 2018; Chrysostomou et al. 2015). Dendrochronological analysis provided thorough chronological range for the Middle, Late and Final Neolithic in Amindeon region and contributed in more detailed study of societies that erected these settlements. Majority of buildings were made of wood as individual piled buildings or grouped on platforms, such as the case with those at Limnochori III and most likely Limnochori II and Anarghiri IXb. Some settlements had even two-storey houses and the massive house models found on site contribute in this direction (Limnochori II, Anarghiri III, and Anarghiri IXa). At particular later stages of these Neolithic villages dried areas were more frequently occupied by buildings made of daub and some had circular shape. Few were established on dry ground or within marshes, such as Anarghiri IXa and Anarghiri IXb. The later had three wooden trackways (one 90 m long) that possibly connected this settlement with nearby village or with fishing spot. In regard to wooden structure, an oval palisade from Anarghiri IXa should be accented as it indicates protective system and diverse social dynamism (Chrysostomou and Giagkoulis 2018; Chrysostomou et al. 2015).

In fact all of these settlements evidence social dynamism regarding their complex and diverse structure, especially if other archaeological material made of wood, clay, and bone is concerned (Arabatzis 2016; Chrysostomou and Giagkoulis 2018; Giagkoulis 2016). They were not entirely pile-dwellings and some had houses of daub, with circular shape or grouped onto platforms, while others were built entirely on nearby dry areas. Some were connected with trackways and others protected by palisades that evidently demonstrates different modes of approachability or enclosure of the communities dwelling within. If compared with the lakeside settlement of Dispillio these pallets of villages in Amindeon region gives further emphasis on the complexity of Neolithic wetland archaeology in Greece. Although so far only two regions of this country display lakeside settlements, still the abundance of archaeological contexts and material from their excavations largely contribute in building of thorough knowledge on wetland communities. The research of all these sites is still in progress and majority of material is not yet published, therefore the forthcoming and new publications will give much better and detailed picture of the Neolithic communities and man-made environment on the lakes of Balkan Peninsula.

Figure 3: Photo of Maliq pile dwelling during the 1960's excavations (Bunguri 2009, Fig. 3).

Albania

There are three lakeside settlements in Albania excavated so far, all on the now drained Lake Maliq. The lake was drained in the melioration process common for the Balkans in the period between 1950's and 1960's, so that the current environment gives different perspective of the eco ambient where these settlements were established. The lake itself faced several changes thus its occupation area was bigger in the Neolithic and significantly increased with the two climatic events in 4200 and 2700 Cal BP (Fouache et al. 2010). Consequently some potential Neolithic lakeside settlements were continuously under water and now covered with lake deposits.

The site of Maliq was found first and excavated between 1962 and 1966 (Prendi 1966). In the first half of the 1970's and at the end of the 1980's there were few smaller archaeological campaigns performed, but mostly focused on later levels (Korkuti 1993; Prendi 1976, 2018). The site has been dated to the Late Neolithic, but without dendrochronological or ^{14}C analysis, thus mainly the pottery was used for the chronological determination (Korkuti 1995; Prendi 1982). Besides the Neolithic levels the stratigraphy and material of the site witness Chalcolithic, Bronze Age and Iron Age occupation as well. Many piles were recorded and thus a palafitte settlement was proposed as one of those erected on the riverbeds or lakeshores (Figure 3). Not much information is given on the wooden buildings and their organisation as in this period Balkan archaeology was mainly focused on classification of Neolithic cultures through pottery and thus such material is mainly present in the excavation reports and regional overviews.

Very close to the site of Maliq there is another pile-dwelling that is extended along the river Dunavec and has the same name. It was excavated in 1971 and 1973 and approximately 90 densely disposed piles were recorded and therefore interpreted as remains of platform (Andrea 1983; Korkuti 1995). The provided figures indicate the form of single dwelling, so that the issue on platform should be further discussed. The piles were burnt in the upper part that implies firing of the settlement, while next to them the remains of floor and walls of daub were unearthed, which confirms the mixture of wood and mud for building constructions. According to unearthed pottery the site was dated in the Middle Neolithic and it seems to be one of the earliest pile dwellings in the Balkans (Korkuti 1995), but the majority of published shards from the first phase are common for the Late Neolithic in the Balkans. The pile-dwelling was the settlement from the first phase, while the second phase evidences the later settlement founded on dry ground. This indicates that in this period the lake level was lower, so that the community inhabiting this village did not maintain the tradition of building pile dwellings, in spite of some other that used wooden dwellings on piles until Bronze Age.

The other lakeside settlement on the Lake Maliq is Sovjan that is approximately 5 km northeast from Maliq. Regarding its structure this site is tell that was cut by the irrigation channels after the drainage of the lake. Due to most distinct remains of piles the research is largely focused on the Bronze Age period and the majority of publication concerns these levels (Fouache et al. 2010; Lera and Touchais 2002). In regard to the Neolithic period only few remains of wooden piles are found and they do not contribute that much in the understanding of Neolithic pile-dwellings of the site, as much as in terms of chronology. Namely, the chronological analysis suggests that the piles belong to the middle of 7th millennium or earlier, which could be one of the oldest wooden remains in the Neolithic Balkans (Lera and Touchais 2002). If the date of the samples is accurate and do not belong to an older wood which was later employed in the Neolithic settlement, than the future excavation of the site can significantly provide more data for the Early Neolithic lakeside settlements. Although still modest, the data from these sites in Albania confirms that the lakeshores on the Balkan Peninsula were frequently used for establishing pile-dwellings.

North Macedonia

The current knowledge of Neolithic lakeside settlements in North Macedonia is also modest and there are only three sites excavated so far. Unfortunately there are no solid reports from the excavations, but several publications concern these sites and provide initial insight into their structures and material culture (Benac 1979; Garašanin et al. 1971; Kuzman 2009; Naumov 2016b; Simoska and Sanev 1976; Zdravkovski and Kanzurova 2016). As in case with Albanian pile-dwellings the main focus was on the material culture and therefore the majority of information is on pottery, figurines, and tools, and not much was specified on wooden constructions. The sites are on Lake Ohrid or in its vicinity and share similar climate conditions that had effect on the settlements established on its shores (Albrecht and Wilke 2008; Hoffmann et al. 2010). They are nowadays in the vicinity or under the cities of Ohrid and Struga and therefore the approach to new data is much harder. Nevertheless, the previous excavation unearthed material culture that could be used for further elaboration of these sites.

Ohridati is a pile-dwelling located right under the city center of Ohrid and close to the lakeshore. The site was found during the construction work in

Figure 4: Photo of Ustie na Drim pile dwelling during excavations in 1962 (Kuzman 2013, Fig. 8).

2003 when a large number of wooden structures were damaged, so consequently a small-scale excavation started in 2006 (Kuzman 2013). The excavation was performed in smaller trench and not much data on pile-dwellings was obtained. The majority of piles were not massive that indicates individual dwellings not grouped on the platforms. Some smaller piles were dug next to bigger ones that could be done for fixing the static of the dwellings or were result of building renewal. Due to tough excavation conditions the spatial organisation of site in this area was hard to determine and thus the absence of information on the number of individual dwellings. Though, they are not on the shore of nowadays lake it questions the vicinity of settlement in regard to Lake Ohrid. Currently there is no information on the lake level in the Neolithic, but most likely it was not that far or at least the pile dwelling was built in the marshes nearby the lake. Along with the pottery many loom weights for nets and harpoons were unearthed that apparently demonstrates that the community was largely focused on fishing and perhaps involved in trade.

The site was initially dated to the Late Neolithic and Chalcolithic that is apparently demonstrated by the pottery. However the dendrochronology analysis performed on two piles indicates a bit earlier dates. Namely, the calibrated dates elaborate the chronological values of 5991-5753 cal BC with 95.4 per cent probability and another of 5616-5378 cal BC also with 95.4 per cent probability (Westphal et al. 2011). These dates are a bit earlier than expected and are common for the Middle Neolithic in Macedonia and the Balkans in general (Naumov 2015; Sanev 1995). Unless the samples belong to juniper tree that was older than the wood used for the buildings on the settlements, it could be one of the oldest dates for the pile-dwellings in the Balkan Peninsula. Also some of the unearthed shards indicate features of earlier decoration, although the majority is common for the Late Neolithic. Nonetheless, two samples are not sufficient for solid chronological sequence and therefore new sampling and dating will be necessary to confirm or reject these quite early dates for a pile dwelling in the region.

Ustie na Drim is a site below the city of Struga, approximately 8 km northwest from Ohrid and was found during the redirection of river channel (Figure 4). The piles of settlements were determined much earlier, but it was excavated in 1962 in a very short weekly campaign and therefore not much data is provided (Garašanin et al. 1971; Koco 1951; Simoska and Sanev 1976). The site was reconsidered later and part of archaeological material was published (pottery, stone and bone tools, and weapons), thus it was determined as Late Neolithic and Chalcolithic (Kuzman 2013; Naumov 2016b; Todoroska 2016). Chronological analysis was never performed, but similarity of pottery with Ohridati indicates close relationship in the initial stages of the Late Neolithic. The variation of piles diameter, as well as their density in particular areas and absence in other parts suggest that there could be combination of individual buildings and platforms. It is worth to note that the settlement itself was not on the very lakeshore, but on the riverbed of Crni Drim next to it, so the community was using simultaneously two resources for fishing. This demonstrates partially a different practice than at other pile dwellings in the Balkans, but in general it fits to the regional features.

In regard to pile dwellings on riverbeds, the site of Crkveni Livadi should be accented. The site was established on the same riverbed as Ustie na Drim, but 4 km north, thus exhibiting the similar regional feature. The excavation was performed in 1956 and 1972, but only short reports from the initial season are published (Pašić 1957; Pašić and Lahtov 1958). It was also excavated in 2012 and 2013, but there are still no publications out of the fieldwork. Due to its specific character this site was reconsidered in the regional overviews of the wetland sites and the combination of pile dwellings and daub buildings was accented (Kuzman 2013; Naumov 2016b). This archaeological context is similar to that of Dispilo and Anarghiri although on diverse waterscape, i.e. river. The flooding of river made similar marshy ambient which initiated the building of smaller pile dwellings as indicated by the piles. These piles could belong indeed to dwellings or fishing huts, but also could be part of fishing system or fences, structures which cannot be refined until more extensive fieldwork. Although sometimes accented as Chalcolithic and Bronze Age site, the pottery from the first excavation seasons and survey (performed where the baggers were digging deep) emphasise the Neolithic levels. This is further supported by the resemblance of pottery to that of Ustie na Drim, Ohridati, and several sites in the region of Pelagonia, so the dating of this site in Late Neolithic is proposed (Kuzman 2013; Naumov 2016b).

In order to date this site thoroughly, as other palafittes in North Macedonia, there is necessity for dendrochronology analysis that can solidly place it into the time frame of pile dwellings in the Balkans. Nevertheless, its pottery indicates the occupation of site from Late Neolithic until Bronze Age that apparently demonstrates the employment of pile dwellings in later prehistory. Other sites in the region additionally contribute in this direction as some that are established on Lake Ohrid, Lake Prespa, and Lake Dojran were active until Iron Age (Kuzman 2013; Naumov 2016b; Naumov et al. 2019, 2018a; Rujak 2014). The one at Vrbnik (close to Struga) was occupied even in the Classical period and the historical sources from that era indicate wooden huts on Lake Prasias (nowadays Lake Dojran), which confirms that reuse or building of pile dwellings was common not only for prehistory (Kuzman 2013; Todoroska 2009). The building of wooden piled huts and trackways was practiced even in the 20th century on Lake Dojran and Monospitovsko Blato, but mainly for fishing purposes (Namičev 2007; Namičev and Namičeva 2016).

Bulgaria

The debate on Neolithic pile dwellings in Bulgaria is still on. There are many coastline sites on the Black Sea, but none is confirmed as a pile dwelling dated to the Neolithic. Five are determined and only Sozopol and Urdovitza on the coast, and Arsenala in the firth are excavated, but the unearthed material ranges from Chalcolithic to Bronze Age. They are even excluded as pile dwellings as there was a significant increase of the sea level between 6500-4000 BP, so therefore these sites were established next to riverbeds and engaged in a maritime trade (Draganov 1995; Ivanova 2012; Peev 2008). The recorded massive piles are so far associated with the Bronze Age levels and there are no published wooden remains or material culture common for the Neolithic.

The same considers the lakes in Bulgaria although there are still discussions on the settlements found close to Lake Varna. Namely, there was continuous research on the lakeside settlements at this lake and even thirteen were documented. Few of them were excavated and it was proposed that they are lakeside settlements with wooden structures (Margos 1973; Todorova and Tonceva 1975). Nevertheless, the current research also indicates that they are not pile dwellings, but common prehistoric settlements built on dry ground next to riverbed (Ivanova 2008; Peev 2008). In spite of the absence of pile dwellings, these sites also lack Neolithic levels thus it cannot contribute to the overview of lakeside settlements from this prehistoric period. As there are thirteen potential sites around Lake Varna their future excavation can change this picture and perhaps provide new data for occupation of this area in the Neolithic as well.

Bosnia

The recently constructed archaeological park at Panonic Lake in Tuzla raised attention to pile dwellings in Bosnia. The evidence for such settlements was obtained at the end of 1950's and since than they were almost absent from prehistoric archaeology. It is apparently questionable whether this archaeological park is consistently reconstructed, as there is scarcity of data associated with the wooden remains and spatial organisation of the site. The archaeological site is now under the city of Tuzla (therefore named as Rudarska Ulica) and it was excavated six decades ago during the urban development of the city. The excavation has provided wooden piles that lead the archaeologists to propose dwellings grouped on platforms (Garašanin 1979). As there is scarcity of data and only one published report of few pages (Puš 1957), it is hard to confirm whether the lakeside settlement had platforms or individual dwellings. Also the presence of lake is not verified although the outflow of the Panonic Sea into the Black Sea was evident long-term process millions of years ago and could contribute in creation of lakes or marshes. Consequently, the area has abundant remains of salt that could be one of the crucial products for trade even in the Neolithic (Nikolov and Bacvarov 2012).

In regard to the site chronology the dating was primarily done on the basis of pottery comparison. It was proposed that the unearthed shards were part of Butmir III culture and synchronous with Vinča pottery, so that it was dated to the Late Neolithic (Benac 1979). Similar pottery was found on nearby site Gornja Tuzla, northeastern from Rudarska Ulica, which was dated in the 1960's with two samples (Vogel and Waterbolk 1963). The later date, belonging to Vinča period, was extracted from a charred beam that could belong to a pile from dwelling, but this should be further confirmed or rejected with the excavations that started in 2007. The recent reexamination of the site also included new laboratory dates that position more precisely its chronology in the second half of 6th century and first half of 5th century (Vander Linden et al. 2014). Nevertheless, without further confirmation of wooden remains from the site it cannot be verified whether this site was a pile dwelling although it was spatially and chronologically close to the one southwest.

Croatia

Besides its richness of lakes and vast sea coastline Croatia still have not evidenced the large number of pile dwellings established in the Neolithic (Benjamin and Črešnar 2009). One of the rare information comes from the site at Zambratija (Histria) where 34 piles were documented during the underwater excavation, as well as the layer with horizontal planks (Koncani Uhač 2009). The small excavated area and the disposition of piles cannot contribute to the understanding of the construction practices and spatial organisation of the site so far. The future research will provide new data on the construction techniques, but also on the chronology of site. According to the pottery found in the excavated area it is proposed that it could be active from Late Neolithic until Bronze Age, but the dating of the wooden boat unearthed nearby proposes much later dates in 1st millennium BC (Koncani Uhač 2009, 2012). These dates should not consider the settlement itself, as the bay was constantly occupied and active, so that the future dating of piles could significantly resolve the chronological issues. It should be noted that in spite of previously elaborated sites this one is not a lakeside settlement, but a pile dwelling established on the sea bay. The pile dwellings in Croatia were also built on riverbanks, but later in the Bronze Age.

The overview of pile-dwellings in the Balkan Peninsula apparently indicates that there are a variety of contexts where they were built. Although many were established as lakeside settlements, there were also some erected on the riverbanks and coastlines. The small number of pile-dwellings on seacoast should not be surprising due to significant change of the sea level since prehistory, thus many of these sites are underwater, destroyed or hard to find. Also there is still no data on Neolithic lakeside pile dwellings in Serbia and Romania, although the settlements were erected on now drained lakes and marshes, but without evidence for wooden structures on stilts. Nevertheless, the current state and future prospects of the lakeside pile-dwellings determined so far provides initial insight into these specific architectonic constructions that were not common in the Balkans as those built of wattle and daub on dry ground or close to marshes. The marshy environment also had effect on sites location and their architectural features, so it could be considered in terms of wetland archaeology.

Wetland settlements

Wetland archaeology mainly concerns the pile dwellings and wooden structures as major focus in its research scopes. If the major publications in this discipline are regarded than there is almost nothing on the settlements in wetland environment that has no remains of pile-dwellings (Menotti and O'Sullivan 2013). This particularly concerns the Balkans that are crowded with marshes, but only few pile-dwellings are recorded. Such selective approach in wetland archaeology is due to long tradition of examining wooden structures and vegetative landscape, and especially in the environment that still preserves well the organic remains. But in spite to fruitful data obtained from pile-dwellings the wetland archaeology neglected a vast potential of sites that were established in waterlogged ecosystem. Due to the modified environment i.e. drainage of lakes and marshes in the 20th century, many of the sites in the valleys are still considered as dryland settlements. However, if the original natural setting is regarded than entirely different landscape was surrounding so called dryland settlements in the Neolithic. Latest research indicates that many of these sites were actually established close to lakes, marshes or bigger rivers that frequently flooded and thus generated wetland environment (Alexakis et al. 2011; Benecke et al. 2013; Naumov 2016c).

They are rarely consisted of pile-dwellings, although these organic structures could be absent due to modern drain processes that have an effect on the firm disappearance of wood. But as the excavations of lakeside settlements in Dispillio, Anarghiri, and Crkveni Livadi indicated there could be combination of pile dwellings and ground buildings made of daub, so that the pile dwellings in the Balkan wetlands should not be excluded. As result to the waterlogged, but preferred setting, some of these settlements were established on the small natural bulks in order to prevent the incoming water, and simultaneously to be in its vicinity for the fertile soil and abundance of raw materials and food (Naumov et al. 2018b; Simoska et al. 1979). Surely, not all of the tells were made on such bulks and many are placed on flat terrains, but majority were close to water communications and therefore occupied in long temporal range, which actually had effect on their mound like outline. In such way, the tells could be considered as one of the most specific features for the Neolithic valleys in the Near East and Southeast Europe. As there are hundreds of tells in the Balkans founded next to now drained lakes, marshes, and flooded rivers only a condensed overview will be elaborated although such relationship with tells and wetlands requires additional study and publication.

Tells

There is more than century as the tells have been excavated, but only in the last decade there is particular focus on the processes of their foundation, regional distribution, spatial organisation, ecological conditions, social processes, and symbolic engagement (Hofmann et al. 2012; Rosenstock 2009). The tells phenomenon is present from the Near East to Central Europe since Early Neolithic until Iron Age, although at this final period of prehistory they are rare in the Balkans. As the Near Eastern tradition the tells were introduced in the Balkans along the process of Neolithisation though majority were not established at the very initial stage of the

Figure 5: Map of the Balkan Peninsula with the location of the wetland regions with Neolithic tells. Greece: 1. Thessaly; Albania: 2. Korça basin; North Macedonia: 3. Pelagonia, 4. Skopje Valley; Romania/Bulgaria: 5. Lower Danube; Serbia: 6. Mačva region; Bosnia: 7. Visoko basin.

Neolithic. Their size varies from very small campsites to momentous fortifications and from simple spatial infrastructure of farming hamlets to complex protourban metropolises.

But besides their quantity and thorough research the tells in Europe are rarely studied in relation to the wetland environment. In major focus were the chronology, formation process, architecture, and material culture, and consequently frequently observed as dryland sites. Therefore in this paper the tells will be reconsidered in regard to wetland environment and a summarised overview on those established in the Balkan marshy and lacustrine environment will be provided (Figure 5). In spite of more detailed elaboration of the Balkan pile dwellings in this paper the presentation of the tell sites will be more condensed. This is due to the very large number of tells on the Balkan Peninsula and therefore only those regions with most specific features will be concerned.

The largest quantity of Neolithic tells is in Greece and Thessaly in particular, which was the first wave of influence by this Anatolian architectural tradition. Many were excavated and thoroughly studied, especially in the direction of continuous social and symbolic processes (Kotsakis 1999;

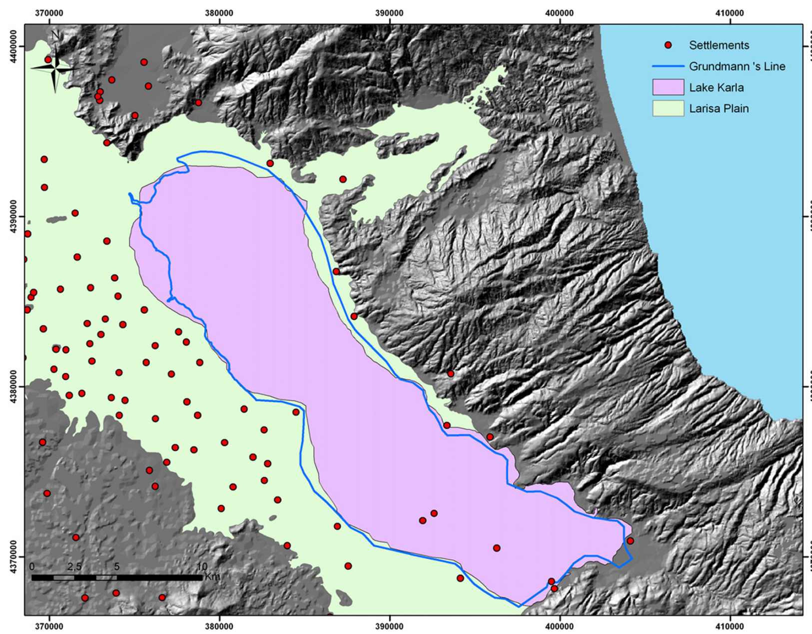

Figure 6: Map with now dried Lake Karla in Larisa Plain, Thessaly (Greece) and disposition of the Neolithic tells in the vicinity of water basin (Alexakis et al. 2011, Fig. 4).

Nanoglou 2001, 2008). However recently the Thessalian tells (*toumba*) were observed in context of the authentic Neolithic environment that concerns the drained Lake Karla as well (Alexakis et al. 2009, 2011; Grundmann 1937). The lake does not exist anymore, but the GIS spatial analysis of tells and geological studies confirmed that many tells were established around this lacustrine area while many others are disposed in its vicinity (Figure 6). These sites may not be considered as lakeside settlements, but the alluvial wetlands were apparently attractive for the Neolithic farmers in Thessaly and therefore many villages were concentrated in this fertile area. This setting is similar to one in the Amindeon region discussed above in regard to pile-dwellings. In this area there were also few tells between the lakes that evidently indicate lacustrine environment as suitable for wetland settlements (Chrysostomou et al. 2015). It could be proposed that there is pattern in the establishment of tells in the Balkan Peninsula frequently associated with lake or waterlogged basins as focal points of inhabitation.

Korça basin in Albania was also elaborated above in relation to pile dwellings, but there were also settlements around now drained Lake Maliq that were not consisted of wooden structures, but mainly of daub. Some of the most remarkable are Podgori, Vashtëmi, Barç, and Sovjan, established in the Early Neolithic around this shallow marshy lake (Korkuti 1995). Some of the dated wooden remains from Sovjan indicate that pile dwelling could be much earlier, but so far these are isolated finds and this cannot be proposed thoroughly (Lera and Touchais 2002). Nevertheless, these sites were initially erected next to waterlogged area and some of them were later developed as pile dwellings, thus maintained the solid relationship with lake and wetland environment.

This pattern of settlement disposal around wetlands and lakes can be traced further to the valley of Pelagonia where the highest density of tells in North Macedonia is recorded (Fig. 7). Approximately 130 tells (tumba or čuka) are documented so far and many are founded in the Early Neolithic (Naumov and Stojkoski 2015; Simoska and Sanev 1976). The recent

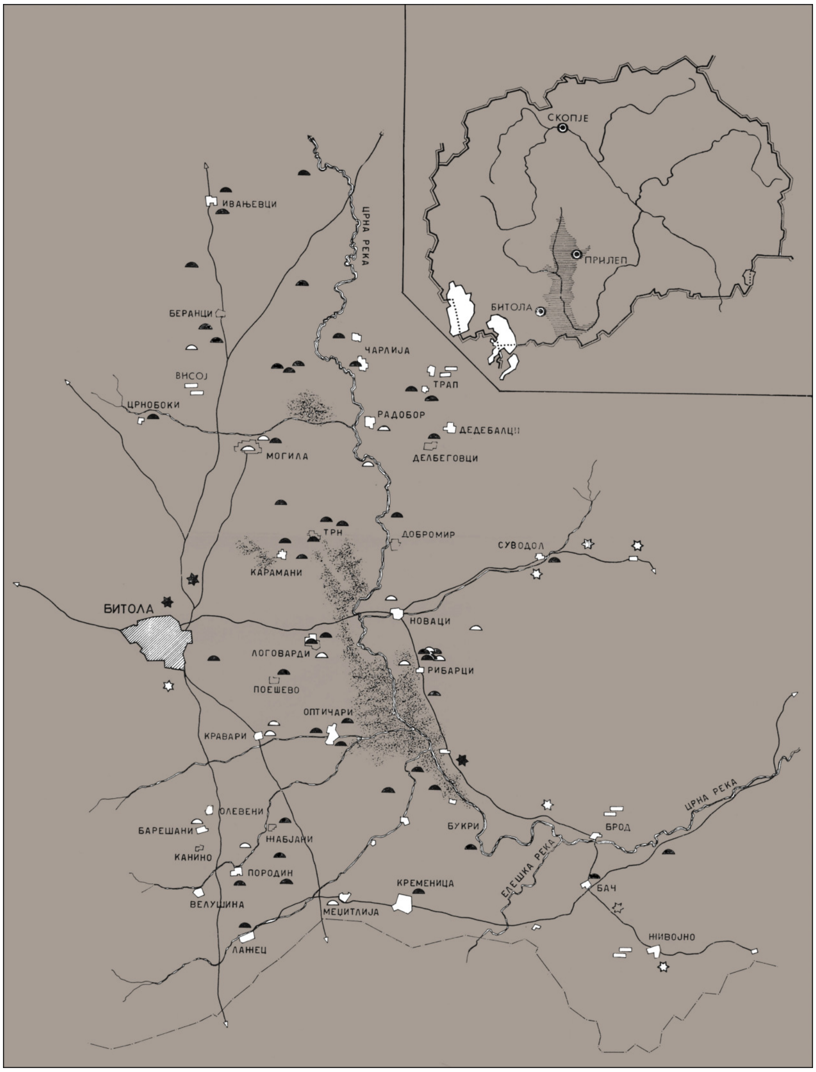

Figure 7: Map with now dried wetlands in Pelagonia (North Macedonia) and the disposition of the Neolithic tells around marshy area (Simoska and Sanev 1976, annex).

research specify that the tells, at least in central part of Pelagonia, were disposed around now drained marshy lakes which were used for fishing and boating until 1960s (Naumov 2016c; Todorovski 2002). This pattern should be tested in other parts of Pelagonia, but it is present as well in other regions in North Macedonia. The Skopje valley is nowadays occupied by the capital city and many of sites were destroyed or vanished in the process of urbanization. But the archaeological excavations recorded number of sites dated in the Middle Neolithic (Sanev 1988, 1989; Stojanova Kanzurova 2011; Tolevski and Stančevski 2017; Zdravkovski 2006). The geological prospection in this area evidenced high fluctuation of Vardar riverbed and consequently vast area of marshes that were dried in the 1950's (Commenge 2009).

The majority of the Neolithic sites were founded next to these marshes as the provision of raw materials and the fertile soils were more approachable than in the upper parts of the valley (Tolevski and Stančevski 2017). It could be noted that the wetland areas were frequently made of shifting riverbeds or floods that partially initiated the development of tells, i.e. mound like settlements a bit higher than ground level. But beside the mound like elevated structure of the tells, the Neolithic communities inhabiting marshes were also aware of pile-dwellings and most likely were building them. In regard to pile dwellings in North Macedonia also Neolithic house models unearthed in Pelagonia should be considered as they could indicate building of wooden constructions on stilts (Chausidis 2009; Naumov 2010; Zdravkovski and Kanzurova 2016). Although there are indications for such buildings on the Pelagonian tells (Naumov and Tomaž 2015), still the thorough excavation and meticulous study of these sites is necessary in order to determine the presence of pile dwellings in the wetlands.

Such setting is recorded in Romania and Bulgaria as well and the Lower Danube area in particular. The fluvial processes generated number of lakes and marshes that were also drained in the 1960s, but detected in the recent studies (Benecke et al. 2013; Hansen 2015). Large number of Neolithic and Chalcolithic sites, of which many tells (*magura* or *mogila*), were recorded and unearthed while some provided highly sophisticated fishing equipment. In Serbia there is similar setting in the region of Mačva where the river Sava create large wetlands due to its meanders and was settled by approximately 50 tells. These smaller tells (*obrovac*) were mainly dated in the Late Neolithic and had ditches that make sort of enclosures to prevent the settlements of surrounding water (Tripković et al. 2013; Tripković and Penezić 2017). The tells, and some with monumental size, are detected and studied in Bosnia as well and many are established in Visoko basin along the Bosna river (Müller 2012). The fertile soil and approachable sources of food and raw materials were attractive for the first farmers in Bosnia although the tells were founded in the Late Neolithic and some were enclosed, a feature common for many tells in the Balkans (Furholt 2012; Hofmann et al. 2012).

It is apparent that the communities inhabiting these settlements based their subsistence on waterlogged proximity, but not only for fishing, provision of reed, and hunting of birds, but also for communication and trade with neighboring and distant communities along the rivers that was sometimes even faster than land routes. In spite of lakeside settlements which were also using boats for transport and communication, the tells on wetlands close to big rivers were socially more dynamic as the communities could reach much larger area by the rivers. Consequently it is not surprising that many tells were established in the Early Neolithic and some were continuously occupied until Bronze Age, while the pile-dwellings in the Balkans appeared a bit later i.e. in the second half of 6th millennium BC. Although the lakeside and wetland settlements were established and active in different waterlogged settings as they were not so diverse except in terms of architecture. The current research demonstrates the interaction between pile-dwelling and tell societies evidenced by abundance of similar material culture (Naumov 2016a). Although functioning in different environments the communities inhabiting these settlements established networks that go much further than the traditional perspective of wetland archaeology.

Lakeside and wetland networks in conclusion

Commonly, the wetland archaeology is mainly concentrated on the communities in lacustrine and marshy areas that are evidenced by organic remains such as wooden pile-dwellings, trackways, palisades, fish-traps, tools, wheels, vessels, baskets, leather, vegetation, and even by human skin and hair. These finds enable a comprehensive insight into prehistoric societies and landscape as never before in the history of archaeology and therefore their consideration in more scientifically based studies. They provide a knowledge that is extremely hard or impossible to obtain from so called dryland sites and consequently stimulated the wetland archaeology to have particular focus on sites with abundance of organic remains. In this process of obtaining fruitful results from sites that are underwater, on lakesides, in peatbogs, moors, and marshes, the wetland archaeology underestimated other prehistoric sites in similar environmental setting that do not provide much information on wooden structures and items, basketry, flora, and skin. There are hundreds of sites in wetlands or in now changed environment that due to climate and geological processes do not have preserved organic remains. The communities were interacting with water and used wood largely, but there is not an evidence for that. And for many years the wetland archaeology was ignoring these societies.

Besides the necessity of incorporation of these sites within wetland archaeology they confirm the dynamic networks they had with the pile dwellings on lakesides (which are of special focus in wetland archaeology). They were equally taking part in social processes and frequently traded with those that are apparently still in the waterlogged setting. In many ways the 'dryland' sites in now drained environment were similar to wetland sites and even shared the same identity on the level of material culture (Naumov 2016a, 2018). Apart from the inevitability of more thorough paleoenvironmental research on the 'dryland' sites they need to be reconsidered within the frames of wetland archaeology and the networks they had going in favor to this.

The archaeological excavation of many Neolithic tells and pile dwellings in the Balkans provided numerous finds that apostrophise the mutual contacts these sites had. In the beginning of cultural-historic archaeology they were elaborated as part of the same cultural groups and their similarities were accented (Benac 1979; Garašanin 1979; Theocharis 1973; Todorova and Vaisov 1993), but due to several reasons the 'dryland' sites were ignored in wetland archaeology. Even with the advantage of processual and post-processual archaeology the modern scientific and theoretical models were not included in the accentuation of their mutual relationship. Nevertheless, the post-processual focus on the issue on identity among the prehistoric societies brought forward the close relationship between various societies, and among tells and pile dwellings in particular (Díaz-Andreu García 2005; Insoll 2007; Naumov 2018). In that direction the material culture substantially supports their dynamic interaction, but also geoarchaeological research had impact with entirely different perspective of environment where the tells were established.

If the later is considered and especially the latest environmental studies in Thessaly, Amindeon basin, Pelagonia, Korça basin, and Lower Danube area, than the waterlogged setting of Neolithic tells is evident (Alexakis et al. 2011; Chrysostomou et al. 2015; Fouache et al. 2010; Naumov and Stojkoski 2015). Thus, the development of these settlements was in similar ecosystem to that of pile-dwellings and only the character of water basins (rivers, marshes, and lakes) incite the communities to adjust their settlements to environmental features i.e. erected tells in marshes and riverbanks, and pile-dwellings on lakes. The future research in the peripheral areas of tells could even contribute with potential pile-dwellings/huts on tells and riverbanks as evidenced in Sovijan, Dunavec, Anarghiri, Mogila, Crkveni Livadi etc. Furthermore, the pottery, stamps, human representations, and tools emphasise the networks that tell and pile-dwelling societies had in the Balkans. Frequently similar vessels and stamp designs, figurines, house models, and gear were found in both wetland and lakeside settlements. For example, Dispillo pile-dwelling has many pots decorated as those on Thessalian tells, the pile-dwellings of Limnochori have identical house models as tells in Pelagonia, while Pelagonian tells have anthropomorphic cylinders, incised vessels, and stamps as those unearthed from pile-dwellings on Lake Ohrid and Lake Maliq (Chrysostomou et al. 2015; Naumov 2016a; Touloumis and Hourmouziadi 2003). This network started first between Early Neolithic tells in various wetlands of Greece, Albania, North Macedonia, and Bulgaria and continued in more complex interaction in Middle and Late Neolithic among tells and pile-dwellings. This relationship can be additionally traced on the level of economy, social processes, and rituals that goes out of the scopes of this paper.

The current research indicates that wetland archaeology should modify its methodological approach and consider these significant networks among tells and pile-dwellings in its future studies, and not only in the Balkans, but also in other regions where there is evident communication between 'dryland' and wetland settlements. Although the Balkan archaeology provided abundance of data in regard to tells and pile-dwellings still it requires more advanced methods in thorough understanding of environmental and social processes among settlements in the waterlogged areas. At some point it could be an advantage that the Balkan archaeology is later involved in wetland archaeology in spite of that in other parts of Europe where it had continuous development for more than a century. With the implementation of current advanced methods and knowledge the Balkan wetland archaeology could considerably contribute in explicit elaboration of wetland societies. This will also have an effect in frequent incorporation of the Balkan tells and pile-dwellings in worldwide wetland archaeology that will contribute as well in the improved and more consistent methodological approach within the wetland archaeology itself.

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On the Edge

The Pile-field of the Neolithic Lakeside Settlement Anarghiri IXb (Amindeon, Western Macedonia, Greece) and the Non-Residential Wooden Structures on the Periphery of the Habitation

8

Tryfon S. Giagkoulis[1]

Introduction

The Amindeon Basin, located in the Region of Western Macedonia (Florina, Greece), is a mountainous plateau characterised by the dominant presence of four lakes: Vegoritis, Petron, Chimaditis, and Zazari (Figure 1.a). This rich hydrographic network was probably quite dynamic until the most recent past, since periodical water fluctuations created extended shallow-water or marshy areas, which combined to the neighbouring woodland and fertile fields, formed an advantageous environment for numerous productive activities of the local prehistoric people. The Rescue Excavations Project launched since 2003 by Florina Ephorate of Antiquities (Greek Ministry of Culture and Sports), aiming to the prevention of archaeological remains highly endangered by the intensive lignite-mining activity of the Public Power Corporation S.A.-Hellas in this region, has yielded substantial new evidence for the existence of a distinct culture, which flourished throughout prehistory to later historic periods and is recently named 'Culture of the Four Lakes' (Chrysostomou and Giagkoulis 2016; Chrysostomou et al. 2015; Χρυσοστόμου n.d.; Χρυσοστόμου and Γιαγκούλης 2018). The discovery of 54 unknown archaeological sites —

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Figure 1: The Amindeon Basin and the prehistoric lakeside settlement Anarghiri IXb. 1.a: Amindeon Basin and the Four Lakes' region (© Google Earth). 1.b: Anarghiri IXb on the edge of Amindeon Lignite-Mining Zone (© Google Earth). 1.c Aerial view from north of the excavation during 2015 campaign (By courtesy of Florina Ephorate of Antiquities).

Giagkoulis, T.S. (2020). 'On the Edge: The Pile-field of the Neolithic Lakeside Settlement Anarghiri IXb (Amindeon, Western Macedonia, Greece) and the Non-Residential Wooden Structures on the Periphery of the Habitation'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 137–155. DOI: 10.11588/propylaeum.714

some of them dating back to Early Neolithic — placed emphatically Amindeon Basin into the map of Greek and southern Balkans prehistoric settlements, creating new research potentials related to the establishment and diachronic development of farming communities. Of particular interest is the documentation of 27 prehistoric occupations in the surroundings of the region's lakes, for which there are strong indications that they were — at least periodically — influenced by water fluctuations. The selective trial trenches and small-scale excavations carried out in eight of these lakeside settlements located mainly on the northern shore of Lake Chimaditis revealed successive destruction layers of burned buildings. Numerous wooden, as well as clay structural elements found in a good state of preservation point to the recognition of the layout of stilted two-storied houses arranged in diverse ways (clusters of houses on platforms or individual structures) along the lakeshore (Chrysostomou et al. 2015, p. 28).

The Neolithic Lakeside Settlement Anarghiri IXb

The site is located on the north-eastern edge of Lake Chimaditis, an area covered by shallow water and varied hydrophilic vegetation until the 1960s, when an extended drainage project to expand arable land took place. This modern intervention, together with the intensification of the lignite-mining activity caused the degeneration of the local habitat, which, according to the so far limited systematic palaeonvironmental studies referring to northern Greece and this specific region, could be characterised as a dynamic wetland along prehistoric times (Bottema 1974, 1982; Gassner et al. 2020; Gkouma and Karkanas 2018; Marinova and Ntinou 2018; Συροπούλου 2010). Although Anarghiri IXb — as well as other prehistoric settlements of the region — was partially destroyed without any archaeological prospection, its existence was documented in 2003, when several test pits at specific areas with visible concentrations of surface material resulted a relative secure estimation of the occupation's maximum size (approx. 2.8 ha). The rescue excavation of the settlement was conducted between 2013 and 2016 as the most challenging endeavor of the Rescue Excavations Project in Amindeon Lignite-Mining Zone, since more than 800 skilled and unskilled workers, 120 archaeologists, and 30 associates of various specialisations were employed in four campaigns. The outcome of this highly-demanding project was the complete excavation of approximately 1.2 ha — mainly on the periphery of the prehistoric habitation — as well as the selective investigation of another 0.55 ha in the central habitation zone, focused on the documentation of the uppermost anthropogenic deposits (Figures 1.b-c).

The study of the enormous amounts of all kinds of artefacts unearthed, together with the investigation of their excavation context is still an ongoing task. At present, the information deriving from the examination of selected trenches' profiles in the Southern Sector of the excavated area enable some preliminary remarks on the settlement's stratigraphic sequence and the general framework of its diachronic development. According to these, the anthropogenic deposits on the periphery of the habitation are nearly 2.5 m thick, while in the central part of the settlement their thickness — as documented on the slopes of the modern drainage canal that destroyed part of the occupation — rise to 3.8 m. Within this relatively thick accumulation of anthropogenic deposits, five archaeological layers were distinguished in the Southern Sector (Layer I-V) (Giagkoulis 2019, Vol. III, Plan 1). Evaluating their components and texture (inorganic and organic materials, sedimentations), the kind of the structural interventions documented (pits, clay structures, structural wood), as well as the recordable differentiations in the state of preservation of the archaeological material, some general notions regarding the development of the occupation could be stated. Namely, the earliest habitation's phase or phases (Layers IV-V) were established in a more or less humid ground; yet, the extent and degree of water's continuous or periodic presence around or within the habitation cannot be estimated at the current stage of the settlement's study. Furthermore, it could be claimed that the accumulation of anthropogenic layers, together with the possible alterations of the water level in the successive periods could have created the conditions for building in a more dry and stable ground (Layers I-III). Insofar these suppositions can be generalized in respect of the settlement's diachronic development, it is proposed that in the lowest layers the remains of a typical wetland habitation were preserved, while the superimposed deposits correspond to a dryland occupation (Giagkoulis 2019, Vol. I, pp. 22-25).

The implementation of a collaborative project of Florina Ephorate of Antiquities and the Laboratory for the Analysis of Radiocarbon with AMS, University of Bern resulted 79 ^{14}C dates of wooden structural elements and other carbonized organic materials deriving from representative layers, architectural units and excavation contexts of Anarghiri IXb (Giagkoulis 2019, Vol. III, Plans 2-6). The earliest activities in the site influenced in some degree by the presence of water are dated in the 55th-54th centuries BC and were gradually intensified — at least on the periphery of the excavated area — in the succeeding 53rd-49th, namely within Late Neolithic I period. In the succeeding 48th-44th centuries BC (i.e. within Late Neolithic II and the earliest stages of Final Neolithic) the settlement was gradually developed into a dryland habitation, while around the 43rd century BC the settlement was probably abandoned.

The Pile-Field

With the exception of the systematic research project conducted since the 1990s by Aristotle University of Thessaloniki in Dispilio (Kastoria Lake, Western Macedonia, Greece) (Facorellis et al. 2014; Karkanas et al. 2011; Χουρμουζιάδης 2008; Χουρμουζιάδης 2002), the rescue excavation of Anarghiri IXb constitutes a unique example for Greek archaeology concerning the investigation in such an extraordinary scale of the deposits of a prehistoric wetland. In the deepest layers of the settlement, the dominant features — among the numerous well-preserved organic materials and finds corresponding to various socioeconomic and ideological activities of the Neolithic community — are the wooden structural remains. The recording of their dimensions, physical characteristics, and possible woodworking techniques, together with their mapping utilising GPS technology and digital photos, created a significant amount of data, processed and analysed using suitable GIS applications. The rarity of cross-reference material from the neighbouring lakeside settlements and the subsequent fragmentary information referring to prehistoric structural wood (Naumov 2016; Oberweiler et al. 2016; Γιαγκούλης and Χουρμουζιάδη 2001, 2002; Χατζητουλούσης 2008) add exceptional

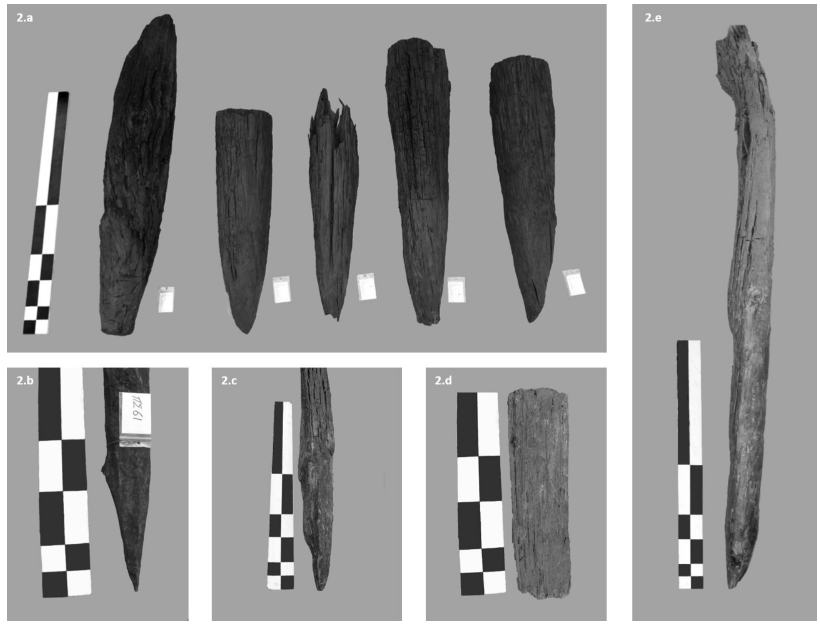

Figure 2: Structural wood from Anarghiri IXb (By courtesy of Florina Ephorate of Antiquities). 2.a: Five extraordinary posts from the northern edge of the excavation. 2.b: Pointed bottom end of a post. 2.c Wedge-shaped bottom end of a post. 2.d Plank 2.e Post driven out from the lowest wet layers of the occupation.

value to the Anarghiri IXb assemblage due to the potentials offered for a multi-level approach of several issues related to building technology, settlement's layout, and spatial organisation.

The database created for the recording and documentation of the settlement's structural wood contains 3648 elements discovered in the lowest wet layers, which cover an area of 11,250 m^2 of the main excavation's sector, as well as 2300 m^2 of an elongated trench on the southern edge of the site. The vast majority of these elements are vertical posts (2871, i.e. 78.7 per cent of total) driven into the marshy soil (regarding the earliest construction episodes) or even into the underlying anthropogenic layers in different depths (Figure 2). Most frequent is the exploitation of roundwood, with some few noticeable examples of half or quarter splits and planks used by the prehistoric builders for construction purposes that are not at present easily distinguishable (Figure 2.d). The length of the posts varies usually from 0.5 to 1.20 m and their diameter ranges from 9 to 12 cm; however, the stratigraphic and spatial distribution of some posts of exceptional length (>2 m) and diameter (>25 cm) could be related to special load-bearing parts of the wooden structures (Figures 2.a, 6.c). In most of the cases the bottom end of the piles was worked to become pointed or wedge-shape with visible tool marks indicative for the implementation of different woodworking techniques (Figures 2.b, c, e).

Considerably fewer (466, i.e. 12.8 per cent of total) are worked and unworked wooden elements deposited horizontally in the lowest layers of the habitation. Their original place and function as structural parts of the prehistoric buildings are difficult to conclude, since there is no secure evidence about their stratigraphic correlation to the neighbouring vertical posts. Nevertheless, in every attempt to suggest any interpretations, a series of depositional and post-depositional processes effecting the formation of the wet layers in a lakeside settlement should be considered (Bleicher 2009, 2013). Similar constraints exist also regarding the extraction of usable information from the examination of a relative small number of thin twigs and small branches (115, i.e. 3.15 per cent of total), although it is worth mentioning that these are found concentrated in a relative small area (*c.* 205 m^2) at the southeastern part of the settlement, where at any rate the density of posts and horizontal wooden elements is notably high. One last category of material is the woodchips found scattered all over the excavation area; yet, it can be assumed that their limited presence in the excavation record (196, i.e. 5.37 per cent of total) might not correspond to the intense woodworking and building activities of the Neolithic community and is directly related to the sampling choices made by the different trench-supervisors of the settlement's rescue excavation.

The systematic sampling of structural wood realised during the last excavation campaigns resulted more than one thousand samples, constituting the first wood-assemblage deriving from a Balkan prehistoric wetland. The preliminary microscopic examination of 805 samples provided useful indications about the preferences of the Neolithic builders in the use of raw material, together with some initial data for the reconstruction of the neighbouring woodland and its possible exploitation and management. According to the results of the species identification, most of the sampled elements (605) are oaks (*Quercus sp.*), i.e approx. 80 per cent of total. One second distinguishable group of 140 trees' stems belong to various conifers (i.e. 18.5 per cent of total). There is also a limited number of samples (12 elements, i.e. 1.6 per cent of total) belonging to deciduous trees' species, namely 8 elms (*Ulmus sp.*) and 4 unidentified ones.

The Wooden Structures

Since the investigation of the earliest layers of the habitation was mainly focused on the peripheral zone of the site, the most prominent outcome of the pile-field's analytical approach was the recognition, description and dating of some accessing and enclosing wooden structures that for now constitute exceptional findings for southern Balkan prehistoric research (Figure 3).

Trackway 2 is an elongated alignment of over 500 posts measuring approximately 85 m, which leads from the probable core of the habitation space to the settlement's edges and even further to its peripheral archaeologically uninvestigated zone (Figure 4.a–b). The structure shows a noticeable variety regarding the exploitation of roundwood and splits and the adoption of woodworking techniques by the prehistoric builders. One of the most interesting construction practices documented in specific spots along the trackways' stretch is the driving into the marshy soil of timbers with side branches (Figure 4.c), a deliberate choice that could have been made to prevent the sinkage of the load bearing posts of the structure (Brunning 2007, p. 115). Together with the closer examination of these technical details, the investigation of the fact that the posts were discovered in different elevations could assist the attempts to conclude whether the layout of Trackway 2 is an outcome of a specific architectural design and structural pattern or it should be most probably related to successive repairs and rebuildings. The calibrated measurements of ten ^{14}C-dated posts from Trackway 2 ranging from 5308-4988 cal BC indicate that the structure was evidently in use for nearly 250-300 years, being at the same time the earliest known wooden accessing structure in Neolithic Europe.

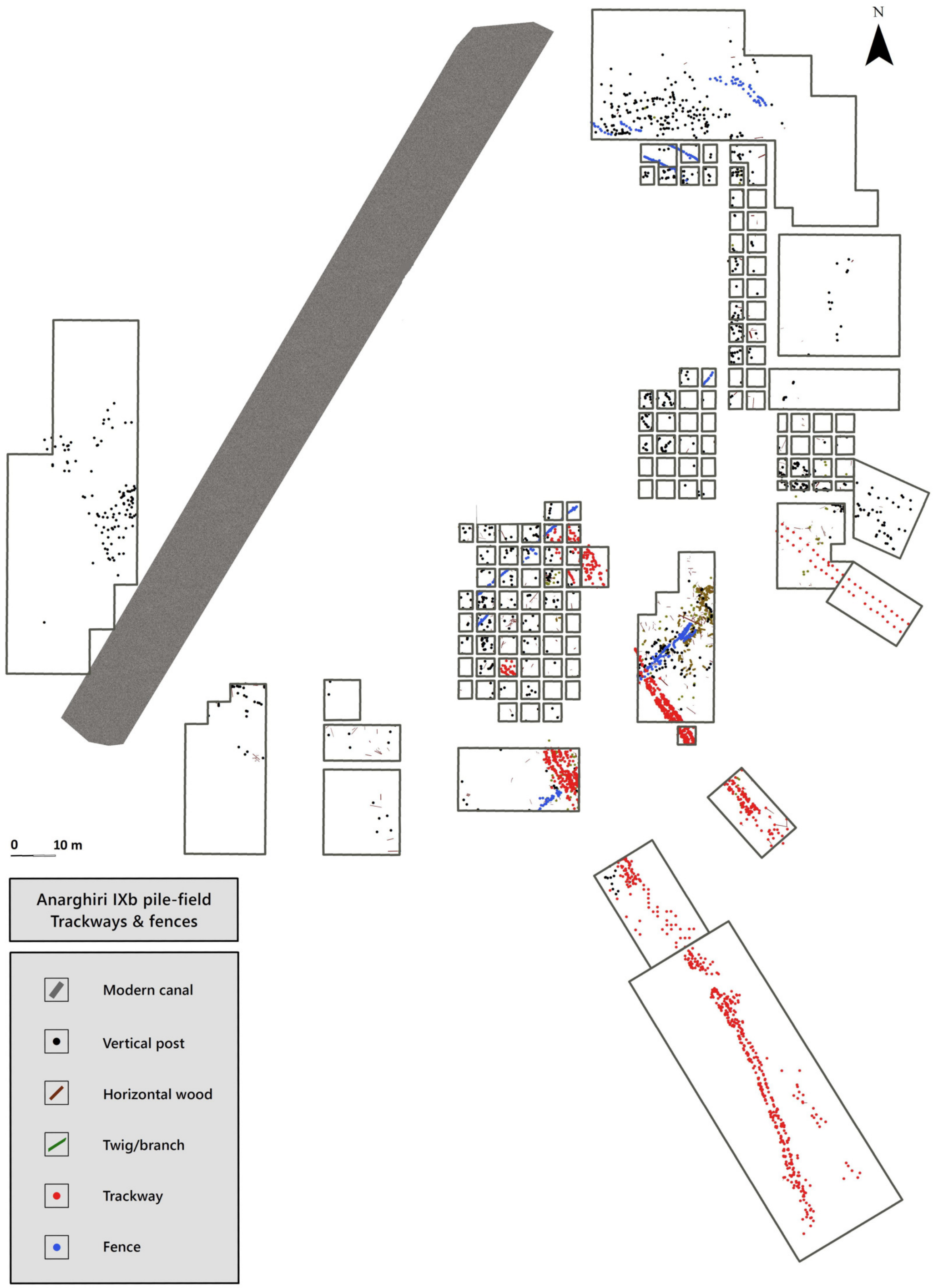

Figure 3: Anarghiri IXb pile-field and the wooden structures of the settlement's periphery (Drawing: T. Giagkoulis).

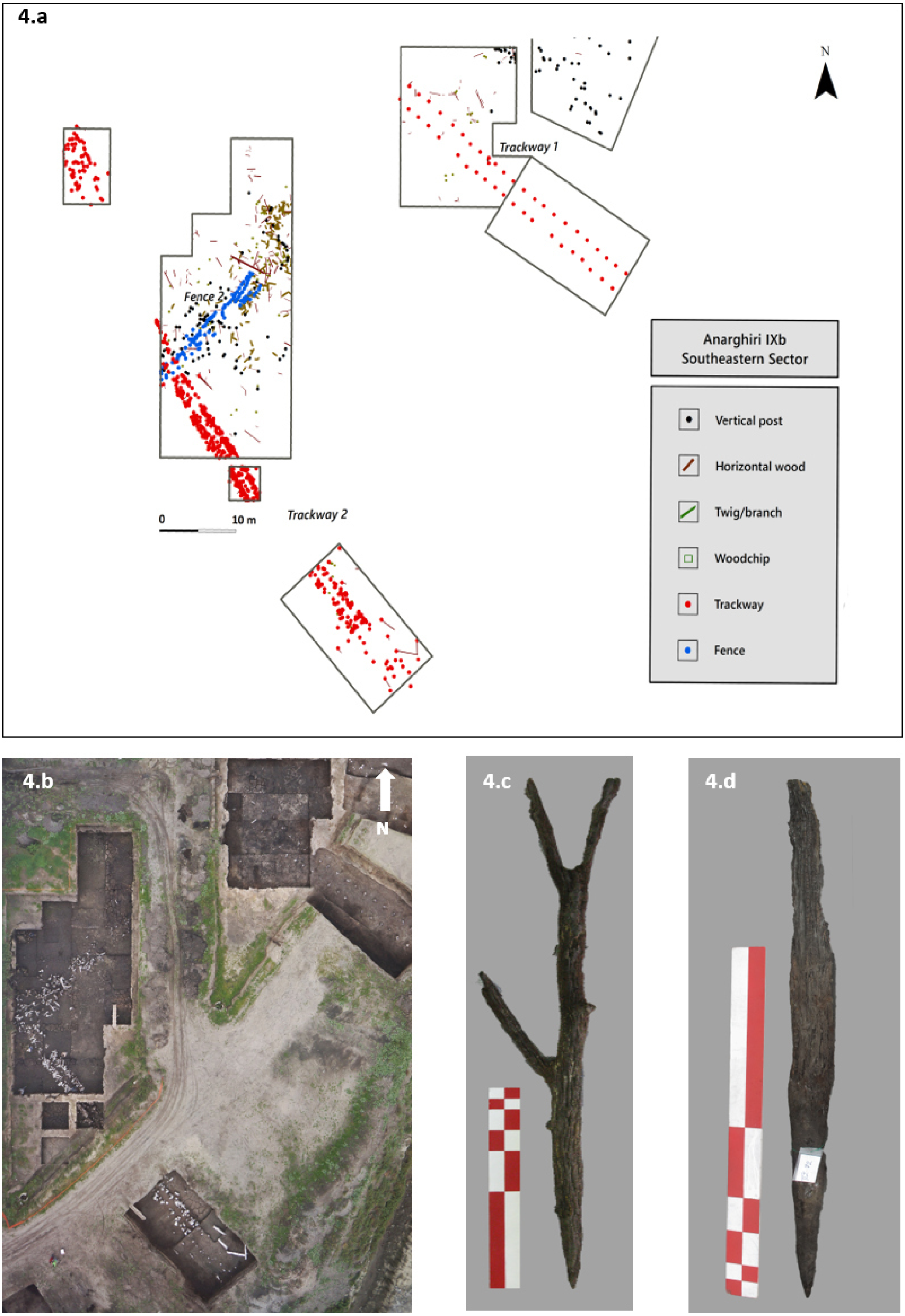

Figure 4: The southeastern edge of the occupation. 4.a: Plan of the pile-field with the remains of Fence 2, Trackway 1 and 2 (Drawing: T. Giagkoulis). 4.b: Aerial view of the excavation's southeastern area (By courtesy of Florina Ephorate of Antiquities). 4.c Post from Trackway 2 with branches and U-shaped top part (By courtesy of Florina Ephorate of Antiquities). 4.d Typical post from Trackway 1 with pointed bottom end (By courtesy of Florina Ephorate of Antiquities).

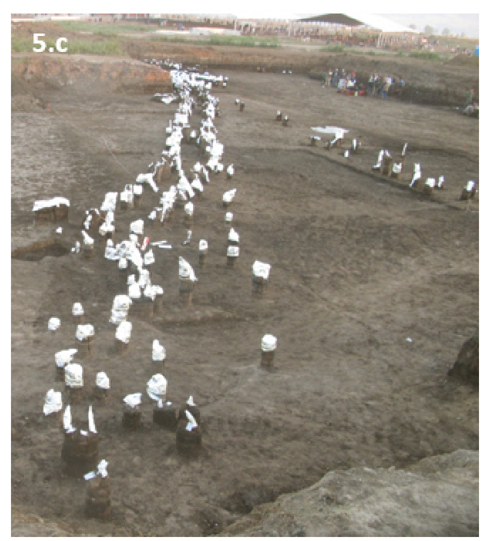

Figure 5: Trackways on the southern edge of the occupation. 5.a: Plan of the pile-field and the remains of Trackways 2, 3, 3a(?), 3b(?) and 4(?) and Fence 6(?) (Drawing: T. Giagkoulis). 5.b: Aerial view of Trackways 3 and 4(?) and the northern edge of the prehistoric dry-land settlement Anarghiri XI (By courtesy of Florina Ephorate of Antiquities). 5.c: View from the south of Trackways 3 and 4(?) and the southern edge of Anarghiri IXb (By courtesy of Florina Ephorate of Antiquities).

Arguably, **Trackway 3** (Figure 5) is the most outstanding wooden structure unearthed so far in Amindeon Basin, not only due to its extraordinary length of approximately 122 m, but also because it was the first definite evidence of certain off-site building activities of the local prehistoric communities. The discovery of this substantial feature in 2013 is not linked to the rescue excavation of Anarghiri IXb, but to the investigation of the outermost limits of Anarghiri XI (Figure 5.b), a dry-land settlement located on a low mound approximately 130 m southeast of Anarghiri IXb with several Early Neolithic to Early Bronze Age occupation phases dispersed horizontally in an area of 11 ha (Χρυσοστόμου and Γιαγκούλης 2018). The foundations of Trackway 3 consist of more than 540 posts driven into the marl of the former marsh (Figure 5.c), where scattered archaeological material was unearthed, mainly handmade coarse Neolithic pottery and several polished stone axes. According to its dating ranging from 5020-4799 cal BC, it is quite probable that Trackway 3 was built by the inhabitants of the wetland to provide access to the opposite shore, probably after the abandonment (or destruction) of Trackway 2; yet, given that in Anarghiri IXb, as well as in Anarghiri XI several occupation phases have been discovered, the exact spatiotemporal associations between the two habitation areas and the specific role(s) that Trackway 3 could play in a wide range of socioeconomic or even ideological activities of the prehistoric communities are still missing.

Although the arrangement of the vertical structural elements and the lack of horizontal wood do not facilitate the exact reconstruction of the two trackways' form, their comparison to similar structures discovered in European wetlands led to the supposition that they were ground-level features comprising a walking surface of horizontal elements retained and supported by vertical posts. Two similar, but partially investigated double posts' row alignments at the Southern Sector of the excavated area were characterized with some reservations as **Trackway 3a(?)** (approx. 4836-4723 cal BC) and **Trackway 3b(?)** (approx. 5208-4800 cal BC), without excluding the possibility that they constituted structural parts or successive repairs of Trackway 3 or some other accessing structure (Figures 5.a, 7.a).

Trackway 1 is the most clearly recognizable wooden feature of Anarghiri IXb comprising a 35 m long and 2.5 m wide double row of 45 oak timbers on the eastern edge of the settlement (Figure 4.a, d). The dating of the structure in the Early Bronze Age (approx. 2577-2469 cal BC) most probably explains its obvious structural differences compared to the earliest features, namely the elaborately processed vertical posts arranged rather regularly to form a bridge-like crossing to the opposite dryland. This feature, together with the slightly earlier remains of the fragmentary double posts' row characterized as **Trackway 4(?)** (approx. 2862-2581 cal BC) constitute for now the only securely dated evidence for human activity during Early Bronze Age in Anarghiri IXb (Figure 5). In any case, it should be kept in mind that at the opposite dryland habitation Anarghiri XI, several features of this period were documented (Χρυσοστόμου and Γιαγκούλης 2018, pp. 219–221).

Apart from the trackways that provided access to the settlement from and to the opposite lakeshore, some other distinguishable posts' alignments were unearthed on Anarghiri IXb periphery, possibly related to the organization and/or delimitation of space and activities. On the northeastern edge of the occupation, a 13 m long double posts' row named **Fence 1**

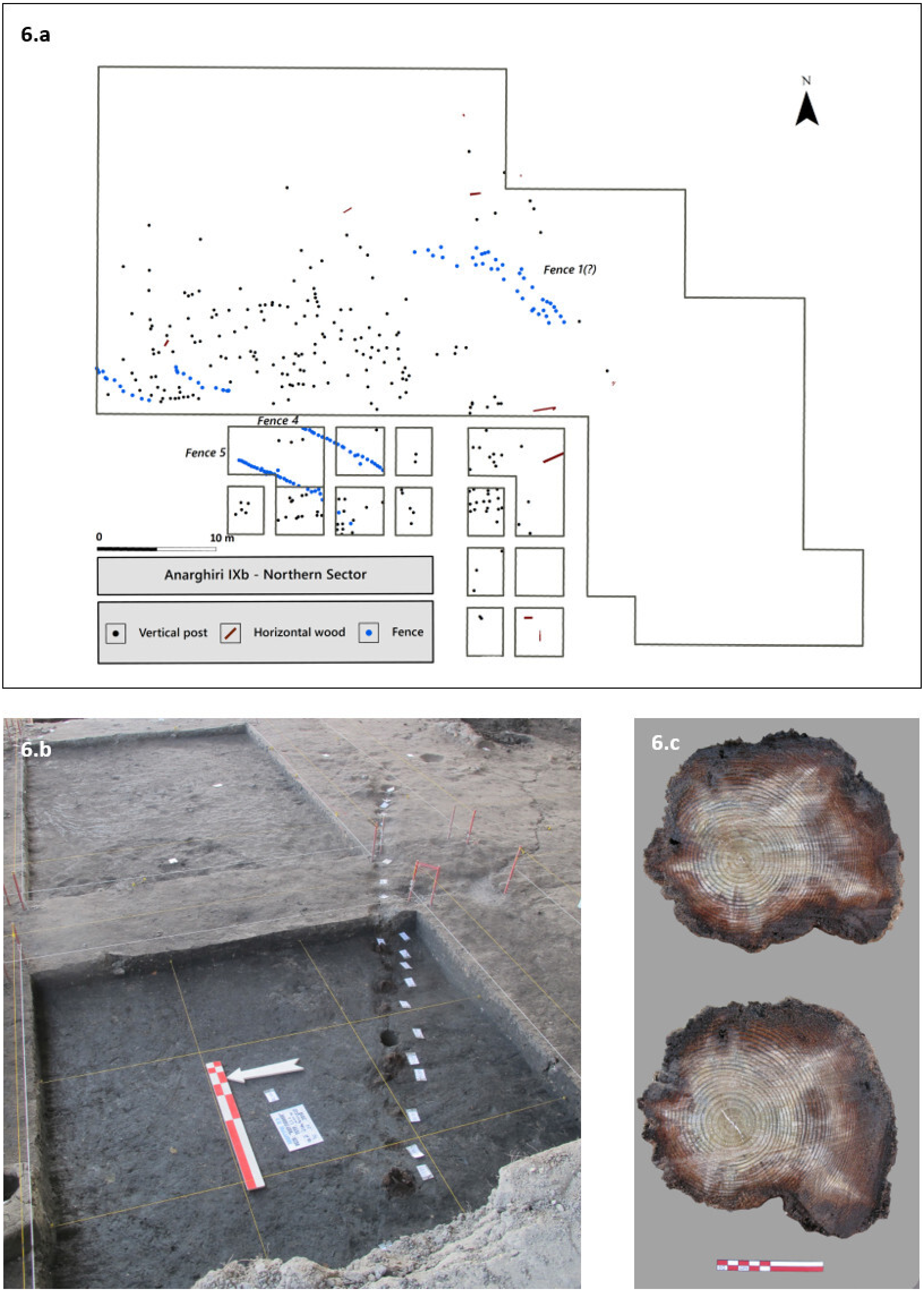

Figure 6: The northern edge of the occupation. 6.a: Plan of the pile-field and the remains of Fences 1(?), 4 and 5 (Drawing: T. Giagkoulis). 6.b: View of Fence 5 (By courtesy of Florina Ephorate of Antiquities). 6.c Samples of posts of exceptional size from the northern edge of the occupation (By courtesy of Florina Ephorate of Antiquities).

could be used as a boundary between the marginal area with very limited anthropogenic activity at northeast, the area which could be characterised as an open space and the denser built area at southwest (Figure 6). The almost identical dates of two opposing posts (approx. 5209-4984 cal BC) seem to support the abovementioned suggestion, at least about the form of this architectural entity. The irregular layout of this structure, with no evident continuity along the neighbouring excavation trenches, poses for discussion interpretative questions related to construction and organisation of space by the prehistoric builders in ways beyond the dominant archaeological perceptions of building design, bringing at the same time up for consideration factors related to a constantly altering wetland environment and to various human activities which can cause the fragmentation of the structure's initial architectural unity. Some few meters to the south of Fence 1, two more linear posts' alignments measuring approximately 20 m **(Fence 4)** and 22 m **(Fence 5)** were unearthed (Figures 6.a-b). The two dated wooden elements sampled from Fence 4 and 5 (5208-5002 cal BC and 5212-5051 cal BC respectively) make quite plausible the suggestion that these two synchronous features were probably parts of bigger structures built as means for arranging space or even enclosing the habitation or a specific area.

The deposition and the density of wooden elements at the southeastern edge of the settlement — namely 825 objects, i.e. 22.6 per cent of total in 560 m^2, 4.12 per cent of the overall excavated area containing wet layers — hold back the attempts to trace any distinctively structured space. But all the same, a more careful focus on the excavation's plans, together with the evaluation of the information resulted by the preliminary examination of the stratigraphic succession, the spatial distribution, and the technical characteristics of the wooden elements, led to the recognition of a 15 m long posts' alignment named **Fence 2** (Figures 4.a-b). The structure, which apparently intersects Trackway 2, constituted of a single row of posts directed from SW–NE for approximately 10 m and ended up in two shorter in length double posts' rows, forming a denser entity, maybe supported by some of the numerous horizontal wooden elements found close to its northeastern part. It should be noted that were no dateable samples from this structure. Nevertheless, the closest – spatially, as well as stratigraphically – date deriving by a charcoal from a neighbouring stratified excavation unit (5299-5076 cal BC), indicates that Fence 2 was probably established and used at the same period with Trackway 2.

Fence 3, a continuous single posts' row measuring approx. 30 m discovered some 40 m to the northwest of Fence 2 towards the central habitation zone, seems to be constructed later than any other Neolithic feature documented (approx. 4668-4464 cal BC) (Figures 7.a–b). The feature is probably combined with the adjacent **Fence 8(?)** (approx. 4668-4404 cal BC) constituting of sixteen vertical posts with curved top part probably for carrying horizontal elements (Figure 7.a, c). Lastly, the fragmentarily excavated alignments characterised as **Fence 6(?)** and **Fence 7(?)** could be parts of larger continuous entities, or even connected with some of the more securely documented structures; still, these suppositions are hardly controllable due to the lack of dateable samples from these two last posts' rows.

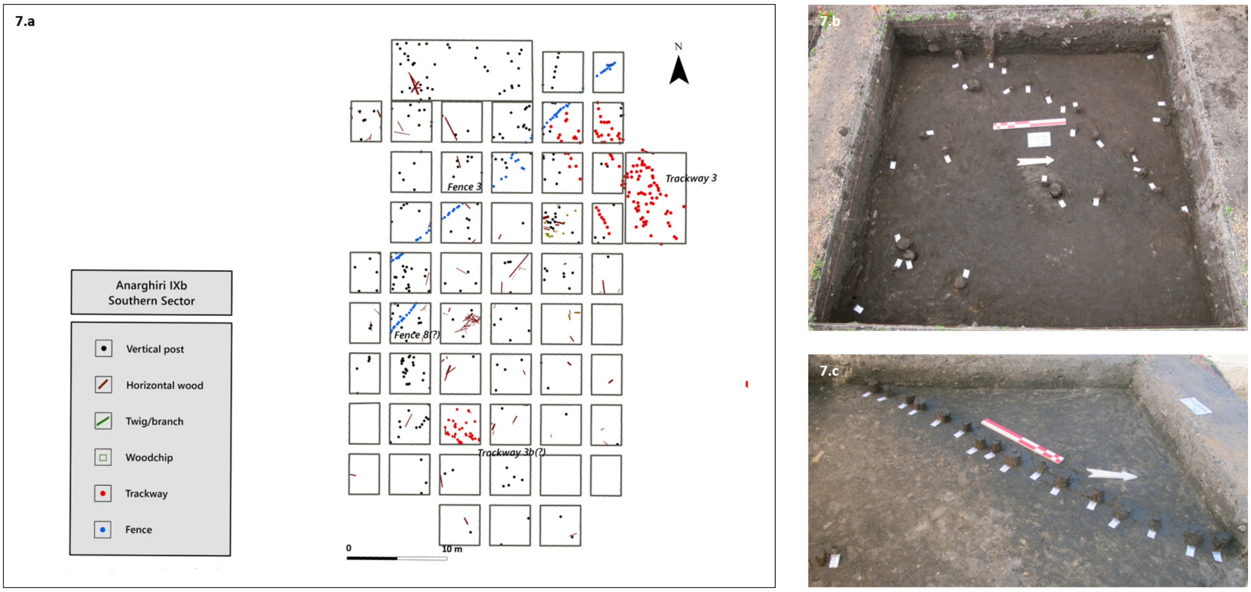

Figure 7: The southern area of the excavation. 7.a: Plan of the pile-field and the remains of Fences 3 and 8(?) and Trackways 2 and 3b(?) (Drawing: T. Giagkoulis). 7.b: View of Fence 3 (By courtesy of Florina Ephorate of Antiquities). 7.c: View of Fence 8(?) (By courtesy of Florina Ephorate of Antiquities).

Discussion

Considering that the overall reconstruction of Anarghiri IXb stratigraphic sequence, pottery and artifact analysis, as well as a series of corresponding studies are pending, the results of the settlement's pile-field analytic approach and the documentation of the accessing and enclosing wooden structures can be currently employed for addressing some general remarks regarding the habitation's peripheral layout and its possible diachronic development. Consequently, it could be supported that Trackway 2 together with Fence 4, 5 and most possibly Fence 2 constitute the earliest recognizable structures established at the marginal zone of the habitation during the Late Neolithic I (namely the last three centuries of the 6th mil. BC), while in the same period the fragmented double posts' row characterized as Fence 1 is dated. Almost immediately after this chronological point at the early-50th century BC Trackway 3 was constructed together with one possible repair of Trackway 3b(?), supposing that this was an individual accessing structure established also in Late Neolithic I. It is worth mentioning that during this last period no recordable evidence for the presence of synchronous enclosing structure is documented. The single available ^{14}C measurement from Trackway 3a(?) pointing to its establishment and use between the late-49th and the late-48th centuries BC constitutes one of the scant evidences of structural activity during Late Neolithic II in Anarghiri IXb. The dating of Fence 3 and Fence 8(?) within the three succeeding 47th-44th centuries BC seems to document in a more tangible way the existence of structural activity in Anarghiri IXb at the beginning of Final Neolithic period. Especially the size and orientation of Fence 3 most probably refers to an enclosing or space-segregating feature which, together with its clear chronological differentiation from the earlier structures, it is further distinguished in terms of location at the edge of the central habitation zone. After the probable abandonment of the settlement around the 43rd century BC, Trackway

4(?) and Trackway 1 constitute for now the only datable evidence pointing to some activity at least at the occupation's marginal zone during the Early Bronze Age.

These suppositions about the concurrence of accessing and enclosing structures during certain timespans within Late Neolithic I lead to the partial reconstruction of the habitation's outline. Accordingly, it can be claimed that Fence 4 and 5 constituted the possible northern demarcation of the residential space, with the synchronous Fence 1 playing some complementary role to this system. Moving towards southeast, the next spatial limitation to be recognized is Fence 2, while its intersection with Trackway 2 should have created a rather distinctive structural complex at the habitation's margins, that according to the big excavation picture could constitute - at least for some specific period - the main accessing point to the settlement from the opposite dryland. The construction of Trackway 3 some meters to the west of Trackway 2 after its probable abandonment could be considered as an indication for the possible dislocation of the main accessing point to the Late Neolithic I habitation, with the general spatial rearrangement of the building activities remaining one open possibility. Even more difficult would be the attempt to detect the extent or the limits of the Late Neolithic II habitation, inasmuch as any building or other activity actually existed in Anarghiri IXb during this period. The successive early Final Neolithic occupation, according to the location and orientation of Fence 3, seems to be shifted towards west-northwest and developed over an area of accumulated anthropogenic deposits that possibly affected the form, as well as the extent of the building activities.

Beyond this inevitably descriptive level of approach, the discussion regarding the non-residential structures on the periphery of Anarghiri IXb has to move a step forward to specific interpretative suggestions. Thus, apart from the efforts for a well-documented reconstruction of the structural form of the wooden trackways in comparison to selected parallels from a great number of structures of different types unearthed in European wetlands (e.g. Brunning 2007, pp. 188–230; Casparie 1987; Eberschweiler 2004; Hafner 2002; Hayen 1957, p. 171; Heumüller 2016; Winiger 2006), the attempt to test some plausible suggestions concerning their function(s) on the edge of the prehistoric habitation, should be more fruitful. The corresponding discussion begins from the obvious use of the structures as crossings, joining the main habitation space of Anarghiri IXb with the opposite dryland exploited as multivariate productive space, being at the same time part of a broader communication network between Late Neolithic settlements within Lake Chimaditis wetland. Although direct indications in Anarghiri IXb material are missing and the dates of the trackways are early enough, it would be intriguing to introduce the discussion that correlates the construction of some central European wooden trackways dating back to the late-4th mil. BC with animal traction and the use of wheeled vehicles documented by the discovery of well-preserved wooden wheels and other components (Petrequin et al. 2006; Schlichtherle 2002). Some researchers argue that the deposition of 'special' artefacts or groups of materials in the wet surroundings of trackways (e.g. Sweet Track in Somerset, UK) is sometimes deliberate and should be associated with symbolic activities performed by the prehistoric communities (Brunning and McDermott 2013, pp. 368–370; Coles et al. 1973; O'Sullivan and Van de Noort 2007). At the same interpretative direction are also pointing the structural and spatial correlation of these architectural features with platforms, buildings or open spaces, to which special ritual function is attributed by the excavators. For example, the 110 m long double posts' row trackway leads from the shore of the Swiss Lake Nauchâtel directly to an exceptional structure with three successive building phases in the central zone of the lacustrine occupation in Station Marin-Les Piécettes dated in the mid-4th mil. BC (Honegger 2001, 2007). Discussing in a more general theoretical level it could be claimed that, since planning, building, and repair of trackways most probably constituted communal labour-intensive endeavours, involving also accurate decision-making, adequate material provenance and management, their construction should have played an active role in the development of intra-settlement dynamic relationships between the occupation's inhabitants, as well as certain interactions between neighbouring communities.

Although the remains of wooden structures related apparently to the demarcation of space on the settlement's periphery are unearthed in a more elliptic scale, there are several topics that could be preliminarily approached. The characterisation of all these linear elongated alignments as 'fences' was preferred due to technical features — namely the average small dimensions of the uprights and their relative sparse positioning — instead of the term 'palisade' which is mainly used to describe more massive and dense structures (e.g. Bauer 2009; Guyan 1967; Meyer 2002, pp. 69–70). This methodological choice consequently brings up the function of these architectural entities in a prehistoric wetland settlement, a question open to many interpretations varying from their possible use as means to reduce impacts from waving water and wind, to separate building and/or productive activities' spaces or to control movement of people and livestock from/towards the main occupations' areas (e.g. Bauer 2009, p. 191; Bleicher and Burger 2015, pp. 121–138; Hasenfratz and Gross-Klee 1995, p. 222; Meyer 2002, p. 70). The most controversial suggestions which associate this kind of structures to defensive purposes are citing variable indications in the archaeological record related to phenomena of violence or warfare even during the Neolithic (Hafner 2010, pp. 359–360; Petrequin and Bailly 2004, pp. 39–40; Torke 2009, pp. 264–269; Viellet 2009, p. 285); yet, a number of these interpretations attributed many decades ago to some of the most exceptional architectural complexes of central European wetlands (e.g. 'Wasserburg Buchau' in Germany) bear the marks of decisive influence of the ideological background of the researchers and their era (Keefer 1992; Schöbel 2008). The discussion in Greek prehistoric research concerning the purposes of encircling neolithic settlements by their inhabitants in various ways (ditches, walls, palisades, pits etc) is as old as the first excavations of Thessalian tells in the beginning of twentieth century and evolved over time focusing on different interpretative alternatives, such as planning and spatial arrangement of buildings and activity areas (e.g. Χατζητουλούσης et al. 2014; Χουρμουζιάδης 1979), increasing antagonism and conflicts among Neolithic communities (e.g. Kokkinidou and Nikolaïdou 2004; Runnels et al. 2009) or demarcation of the settlement's, as well as community's boundaries in a symbolic — together with the actual — level (e.g. Chapman et al. 2006; Kotsakis 2006, 2009; Pappa 2007).

Afterword

Taking into consideration the recent theoretical and methodological trends in the research of the European prehistoric wetlands (e.g. Hofmann 2013; Hofmann et al. 2016), it is self-evident that decoding pile-fields and studying structural wood constitute the basic steps of any interpretative attempt to understand wetlands' layouts and investigate their spatial organisation. For the moment, it would be rather premature to expect any synthetic assumptions from the study of Anarghiri IXb assemblage directly comparable to those resulted by the multidisciplinary approach adopted for the analysis of the material recently discovered in the Alpine region (e.g. Bleicher and Harb 2017). Nevertheless, a succeeding level of analysis of selected well-preserved samples would utilise the advances made the last few years by European dendro-archaeologists, aiming to widen the spectrum of future research objectives with topics related to woodland management, dendroprovenance, and reconstruction of local wetland microenvironment (e.g. Billamboz 2011; Bleicher 2013; Suter and Francuz 2010). In addition, the samples' assemblage from Anarghiri IXb together with structural wood collected from other neighbouring prehistoric wetlands, can constitute the core of a significant archive for the introduction of dendrochronology in Greece, as well as in southern Balkans. Until then, the contextualisation of the archaeological evidence from Anarghiri IXb into the dynamically developing discussion concerning the Neolithic communities of northern Greece is already a challenging desideratum. One fresh impetus for the achievement of this objective could be given by the growth of wetland archaeology in Western Macedonia, a region that, except from being acknowledged as the birthplace of Greek wetland archaeology due to Dispilio Excavations, can become a focal point for the in-depth approach of the distinct living-by-the-lake cultural phenomenon in southern Balkans.

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A new look at late Neolithic plant economy from the site of Zürich-Parkhaus Opéra (Switzerland): methods, activity areas and diet

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Late Neolithic plant economy north of the Alps

Research on Late Neolithic agriculture and wild plant gathering (during the last third of the 4th millennium cal. BC) has been intensive in the Alpine Foreland (Jacomet 2009; Jacomet and Brombacher 2005; Jacomet et al. 2016). This is particularly true in connection to lakeside settlements, with their extraordinary preservation conditions that allow for large amounts of plant remains to be preserved in an uncharred state, having an enormous interpretive potential (e.g. Jacomet 2013). Despite one might think that our knowledge on this period can hardly be improved, recent research at the site of Zürich-Parkhaus Opéra (from now on ZHOPE) meant a step forward in our understanding of Late Neolithic plant economy in the region and prove that a lot of further potential is hidden in those waterlogged deposits. A big part of this step forward was achieved by implementing methods of systematic analysis that are the result of a constant revision of the procedures followed in previous research with the goal of achieving a standardised methodology that allows the best results possible with a reasonable time frame. The aim of this paper is to present some of the main contributions of the work done to date and some hints of what further research on this site will provide in coming years.

What is then actually known about plant economy in the last centuries of the 4th millennium cal. BC? We will focus our statements on the Western Alps, since research north the Austrian Alps is not yet in a good state (Jacomet, 2006), although significant improvements are expected from running projects. At a chronocultural level, this period is within the so-called Horgen Culture (ca. 3400–2850 cal. BC) in the region between western Switzerland and lake Constance (see e.g. Jacomet 2007).

One of the drawbacks of previous research is the quality of sampling and the representativeness of the analyses, which, for several reasons, was often limited (see an overview in Jacomet and Brombacher 2005). The site of ZHOPE, with two Horgen settlement layers (no. 13 and 14) spreading over large areas, was the perfect scenario for implementing an ideal *surface* sampling program and target many of the questions that had since long (e.g. Jacomet et al. 1989) been formulated.

Agriculture during the period between 3400 and 3000 cal. BC involved several cereals, mostly naked wheat (typically of the tetraploid type, *Triticum durum/turgidum*), emmer (*Triticum dicoccon*), and barley (mostly of the multi-rowed naked type, *Hordeum vulgare*). Besides, pea (*Pisum sativum*), flax (*Linum usitatissimum*), and opium poppy (*Papaver somniferum*) were also cultivated. It was emphasised in previous work that pea (*Pisum sativum*) must have been regularly cultivated, but that it was underrepresented in our records (partly due to the difficulties in the identification of

Antolín, F., C. Brombacher, M. Kühn, B.L. Steiner, N. Bleicher, S. Jacomet (2020). 'A new look at late Neolithic plant economy from the site of Zürich-Parkhaus Opéra (Switzerland): methods, activity areas and diet'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 157–172. DOI: 10.11588/propylaeum.714

uncharred fragments of pea pods) and therefore impossible to establish its importance in the economy (Brombacher 1995, 1997; Brombacher and Jacomet 1997; Favre 2002; Hosch and Jacomet 2004; Jacomet 2006, 2009). Only at Hornstaad Hörnle I, a site in lake Constance that dates ca. 3900 BC, were concentrations of uncharred pea pods found (Maier 2001), mainly because they were very well preserved. Even at Torwiesen II, a site located nearby lake Federsee in Germany and dated to ca. 3300 cal. BC and studied by the same researchers, no remains of pea pods were found (Maier and Herbig 2011). This problematic was directly approached during the analyses of ZHOPE and the criteria for identification of legume pods (probably pea pods, but with an unsure identification to species level) were finally established. This was too late for the first analyses of layer 13, and they were only properly quantified for layer 14 (and in the second phase of analyses of layer 13).

Flax could have been mostly used to gain oil, according to some researchers who observe a correlation between the finding of capsule fragments and seeds. This type of assemblage would be the residue of oil production that could have potentially been given to animals as fodder. The use of plant oil (likely from opium poppy and probably also from flax) to treat antler tools was proven by organic residue analysis ZHOPE (Spangenberg et al. 2014). At Arbon Bleiche 3, a site dated to ca. 3400 cal. BC and located at the southwestern shore of Lake Constance, it seems that, in addition to their use for production of oil, also seeds would have been consumed on their own, since large accumulations of capsule fragments were found in intervening spaces between houses (Hosch and Jacomet 2004). Spindle whorls were found in most houses at Arbon Bleiche 3, so it is assumed that weaving took place in all of them, but probably not from flax, which requires a very intensive processing. Most of the textile fragments found at the site come from lime bast fiber (Hosch and Jacomet 2004).

The importance of flax and opium poppy during this phase, together with the increase of importance of emmer in relation to naked wheat, has been connected to an impoverishment of the soils. There are further hints for this, such as the weed spectra of some of the investigated sites in lake Zürich, including taxa such as *Vicia tetrasperma, Euphorbia exigua,* and *Trifolium arvense* (Brombacher and Jacomet 1997). Other possibilities have also been proposed, such as a lower influence of southwestern groups on the economy of the Horgen Culture. This could also eventually explain the lower amounts of naked wheat found towards the end of this period, in favour of emmer and flax (Jacomet 2006), considering the fact that naked wheat does not seem to be an important crop further east (Kohler-Schneider 2007; Kohler-Schneider and Caneppele 2009). It must be noted, though, that an increase in hulled wheat agriculture is also observed in the Jura region (Schaal and Petrequin 2015) and in other regions of particularly northern France (Martin et al. 2016). At the same time, there is indication of an intensification of farming in this area, with more weeds typical of winter-sown fields that would be kept fertile over long periods (Jacomet et al. 1989).

Regarding edible wild plants, the large amounts of diaspores recovered in lakeshore sites has been the basis to propose that gathered plants made an important contribution to human diet in the Neolithic. Previous modelling work concluded that between 20 and 50 per cent of the daily calories were obtained from wild plant resources (Gross et al.

1990). Calculations from the site of Arbon Bleiche 3 based on the total amount of remains found in the analysed samples, concluded that up to ca. 50 per cent of the caloric intake from plant resources would come from wild plants. For these calculations hazelnuts (*Corylus avellana*) and acorns (*Quercus* sp.) were used (Hosch and Jacomet 2004). The TKG (thousand grain weight or *Tausendkorngewicht*) was used to calculate the total amount of weight (and therefore calories) represented by the different taxa in Arbon Bleiche 3. The results were as follows: barley: 1 per cent; emmer: 8 per cent; naked wheat: 22 per cent; flax: 28 per cent and opium poppy 1 per cent; hazelnuts 35 per cent; and acorns 2 per cent.

Other important gathered plants could have been wild apples/pears (Maloideae) and bramble/raspberry (*Rubus fruticosus/idaeus*), among others. Large concentrations of hazelnut shells have been found in several sites, such as in House 14 in Arbon Bleiche 3 (Hosch and Jacomet 2004) or in Horgen Scheller, a site located south of Zürich, on the western shore of Lake Zürich (Favre 2002). Similarly important concentrations of crab-apples are known from the Horgen layer 3 of Mozartstrasse (Jacomet et al. 1989), in Lake Zürich. Some taxa could have been favoured by a higher human impact on the landscape during the Late Neolithic, and this could explain the increase of sloe fruits (*Prunus spinosa*) (Brombacher 1995, 1997). Hazelnuts and crab-apples have also been reported as being extremely abundant further east (Kohler-Schneider 2007). The role of some of these plants in human diet is not clear though, particularly for acorns and achenes of beech (*Fagus* sp.), although it seems plausible that they were gathered and stored for human consumption (see discussion in Hosch and Jacomet 2004). A significant negative correlation between acorns and hazelnuts in Horgen Scheller was also interpreted as evidence of the use of acorns as fodder at the site (Favre 2002).

This paper will present some of the most relevant outcomes of the ZHOPE project so far, and some of the fields in which current and future research at the site will focus:

- Basic methodological aspects: sample volume, sieving strategies, quantification methods, etc.
- Approach to the role of certain resources that had been to date underrepresented in the studies: large-seeded wild plants in general and domesticated pulses
- Use of GIS for the identification of activity areas at the site
- Detailed dietary analysis based on the total number of fruit remains from the full range of crops and edible wild plants present at the site.

The aim of this paper is to share some of our experiences regarding these aspects, without aiming to demonstrate each of the statements proposed, since most of them have been treated in other publications that will be quoted as a guideline for further research on each topic.

The site of Zürich-Parkhaus Opéra. The sampling and sieving strategy

Zürich-Parkhaus Opéra (ZHOPE) is located in the northern shore of lake Zürich (Switzerland) (Figure 1). It was a large excavation of over 3000 m^2 that took place during 2010 and 2011 (Bleicher and Harb 2015). Up to 8 settlement phases were detected in this area. This study is based on the samples from the two Horgen layers number 13 (dendrodated to 3176–3153 BC, representing one settlement phase of no more than 25 years) and number 14 (dendrodated to ca. 3090 BC, of unknown duration) (Bleicher and Burger 2015). The preservation of both layers was not comparably good, being layer 13 better preserved over a larger surface, while layer 14 was well preserved in a smaller area (Figure 2). This was tested through a taphonomic analysis of plant macroremains as indicators of layer formation processes (Antolin, et al. 2017). Both layers are strongly organic and contain large amounts of plant remains, including lignified and non-lignified tissues such as leaf blades. A total number of 27 constructed features and a fence were identified for layer 13 and 9 constructed features for layer 14 through dendrochronological analyses (Bleicher and Burger 2015).

Having a multi-phase lakeshore site representatively sampled involves more revision and controlling than most of dry sites. In this particular case, house plans cannot be defined during fieldwork or soon after it. They require dendrochronological analyses, which may take several months, if not years, to be conducted. In the meantime, all the information that is available for archaeobotanists is the information connected to the sample, if the samples were recorded in a database, and the sample in itself. For this reason, the nature of the sediment samples was described before sieving and they were later assigned to the part of the layer from which they had been obtained (base, intermediate or top position), relying on the field documentation. Following previous research, it was the aim of our sampling strategy to obtain up to 8 samples per habitation unit or construction unit (Hosch and Jacomet 2001), a reasonable number of samples from intervening spaces between houses, as well as from different types of sediments (loam-rich, organic-rich, sandy-rich) and special features such as burnt layers (for the latter, for instance, it was established that 10–20 samples were enough to characterise their homogeneity/heterogeneity (Jacomet et al. 1989). Deciding which samples had to be analysed was therefore a multi-step process that started with a systematic type of interval sampling (1 sample every second meter from the parts of the site that were excavated in detail), and it was continued with a more targeted sampling oriented to the obtention of enough samples per constructed unit and particularly enough samples from the intervening spaces between houses and the burnt layer. This strategy was only possible because ca. 2000 samples were taken during fieldwork, systematically, every second meter. Those samples are still today stored in a dark storage facility under constant fresh conditions in case some further sampling is needed. Had it been organised otherwise, there would not have been any chance to go back and expand the sampling strategy upon request.

The sampling and sieving strategy was described in previous publications (Antolín et al. 2017a,c, 2015; Steiner et al. 2015, 2017). Its main goal was overcoming two traditional limitations in most previous investigations. Firstly, having the whole surface of the site sampled and that the volume

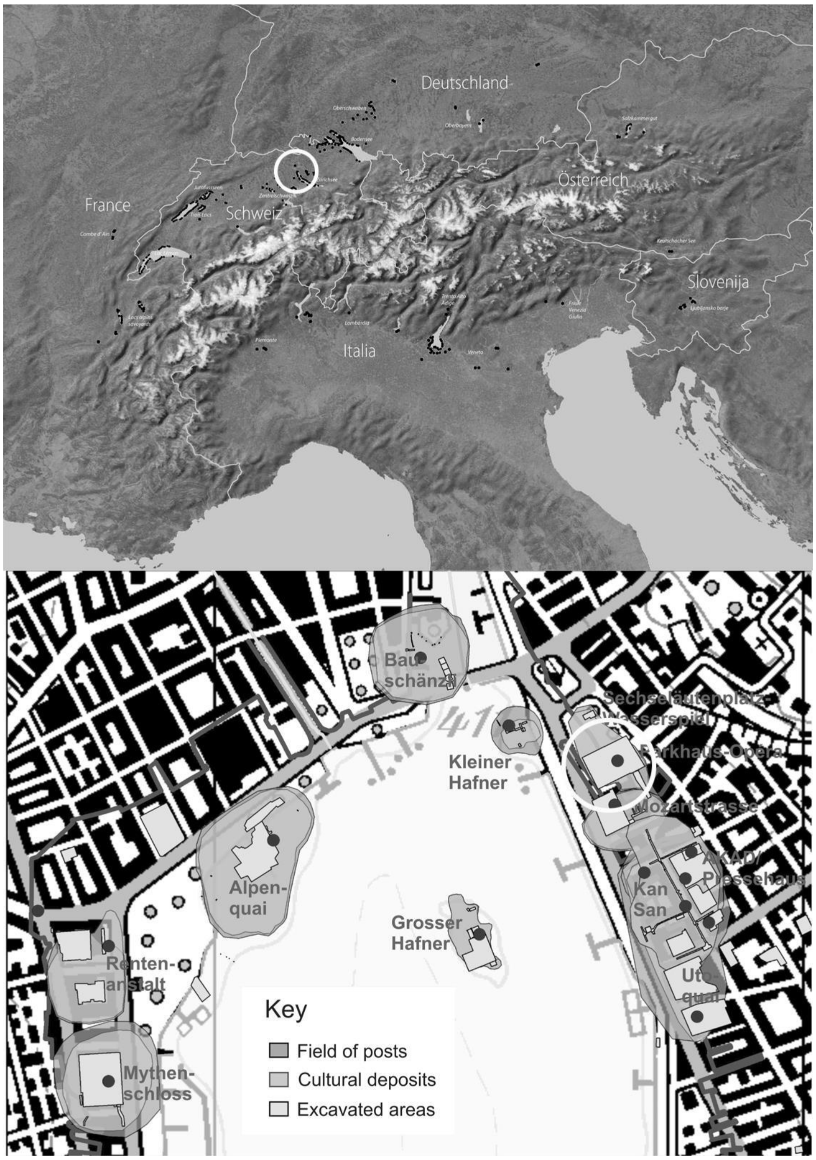


Figure 1: Location of the site at a wider scale (above) and in the northern shore of Zürich lake (below) (Antolín, et al. 2016).

of the samples was enough to have not only small-size plant remains (such as cereal chaff or flax seeds) but also large-size seeds and fruits (such as acorns, hazelnuts, and charred grain) in a representative number. Secondly, it was our aim to establish a methodology that could be used in other similar sites with good preservation and not particularly thick cultural layers (i.e. less than 40 cm). This methodology should aim for excellent results in the shortest time span possible. Several tests were performed to improve our methods (Antolín et al. 2017a,c, 2015; Steiner et al. 2015, 2017). The wash-over technique combined with a freeze-thaw pre-treatment (Vandorpe and Jacomet 2007) was used in order to recover plant diaspores, including the most fragile ones which can get destroyed during regular water sieving (Hosch and Zibulski 2003). Each master sample was subdivided into two sub-samples: one of ca. 3 L (the so-called A-samples) for large-seeded remains, to be sieved down to 2 mm; and one of ca. 0.3 L (the so-called B-samples) for the small seeded remains, to be sieved down to 0.35 mm. Despite the risk of obtaining slightly biased re-

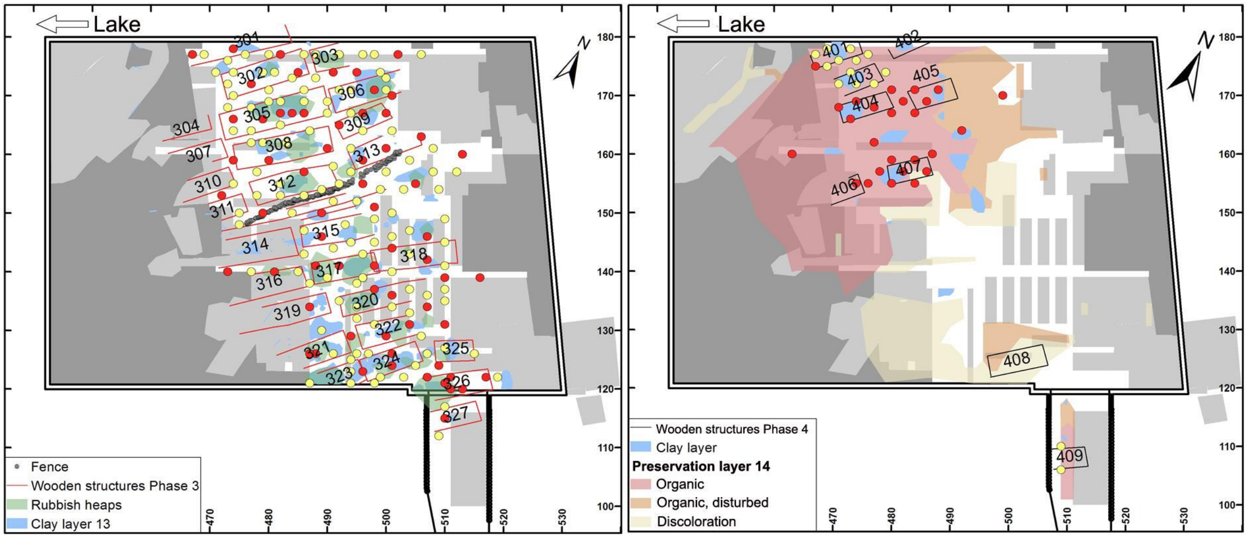


Figure 2: Samples taken at ZHOPE. Red dots indicate A-samples, yellow dots A- and B-samples (Antolín, et al. 2017).

sults in the smallest subsample, this allowed reducing the sieving time for large samples and as well as deciding which samples were needed in order to record small-sized remains representatively. In total, 256 samples (123 of which were sieved down to 0.35 mm) of layer 13 with a total volume of almost 1000 L were investigated until 2016 (average sample volumes of 3.8 L), while new analyses are still unpublished (ca. 60 additional A- and B- samples). The data regarding large-seeded plant remains refers to the total number of samples, small-seeded plant remains were exclusively analysed in the 123 samples mentioned above. Regarding layer 14, 53 samples were sieved and 33 of them down to 0.35 mm.

ArcGis (ESRI 2010) was used to represent on the site plan the densities of plant remains obtained per sample by means of graduated symbols with sizes defined by the Jenks natural breaks classification method (Jenks and Caspall 1971).

Methodological observations towards a better comparability of the data

It was observed during research at ZHOPE that instruction files for all the steps in the sample preparation and process of analysis need to be written before the project starts. This is the only way to provide the same detailed instructions to the whole team. Even in these ideal conditions, inconsistencies take place and for this reason sieving tests need to be carried out when multiple operators work in parallel (Steiner et al. 2015). It was repeatedly observed that what is quantified in each fraction is of major importance for the comparability of the data and different tests (Antolín et al. 2017c; Steiner et al. 2015, 2017) allowed defining a set of counting units in each fraction (Table 1). This is only to be applied in similar large-scale studies, and not for the most common monolith samples or profile samples.

Table 1: Recommended guidelines for the recording of botanical macroremains (currently used in the analysis of Parkhaus-Opéra) (Antolín et al. 2017c). p/a stands for presence/absence.

Taxa/type of remain	**State of preservation**	**Counting unit**	**Quantification (2mm fraction)**	
			A-samples	**B-samples**
Cereal grains	charred	with embryo	full	full (only when no A-Sample is analysed)
Cereal bran	waterlogged	>2mm with hilum	full	full (only when no A-Sample is analysed)
Cereal chaff	waterlogged and charred	glume bases (glume wheat) or rachis segments (naked wheat and barley)	full	full
Flax (*Linum usitatissimum*) capsules	waterlogged and charred	≥2 capsule fragments, with apical ending	full	full; single capsule fragments with apical ending
Flax (*Linum usitatissimum*) seeds	waterlogged and charred	with hilum	semi (only when no 0.35mm fraction is analysed)	full
Opium poppy (*Papaver somniferum*) seeds	waterlogged and charred	whole seeds or halves	p/a (only when no 0.35mm fraction is analysed)	full
Amorphous charred objects	charred	>5mm	full	full
Rubus fruits	waterlogged and charred	whole seeds	semi (present, some, many)	full
Corylus/*Fagus*/*Quercus* pericarp	waterlogged and charred	5x5mm	full	full (only when no A-Sample is analysed)
Malus/*Pyrus* pericarp	waterlogged and charred	3x4mm	full	full (only when no A-Sample is analysed)
Large seeds/fruits (incl. *Najas* and *Aethusa cynapium*)	waterlogged and charred	whole or >1/2	full	full (only when no A-Sample is analysed)
needles of coniferous trees	waterlogged and charred	needles with apical ending	semi (present, some, many)	semi (present, some, many)
Smaller seeds/fruits	waterlogged and charred	whole or >1/2	p/a (only when no 0.35mm fraction is analysed)	full

We do not want to introduce the study of taphonomic variables in this paper, but guidelines for their recording and study were also developed and published elsewhere (Antolín et al. 2017b).

The recording of the data was done on pre-designed paper sheets, where all the variables and commonly found taxa were already introduced to minimise writing time during analysis. The data were stored in an Access database called ArboDat (© Kreuz and Schäfer, 2017), which facilitated their systematic recording. Specific effort was put so that identifications by all project collaborators were homogenised, providing the codes and rest types to be introduced in the program beforehand (see Anhang 1 in Antolín et al. 2017a).

General results of the archaeobotanical analyses at ZHOPE

Archaeobotanical analyses at the site allowed for the identification of around 225,000 plant macroremains (mostly seeds and fruits) from layer 13 and 40,000 for layer 14. Cultivated plants were well represented in the record, particularly cereals and oil plants. Among the cereals, emmer (*Triticum dicoccon*), and naked wheat (*Triticum aestivum/durum/turgidum*, mostly belonging to the *durum/turgidum* group) are better represented in the uncharred record, while barley (*Hordeum vulgare*, multi-rowed and mainly of the naked type) is one of the most important cereals when considering the remains preserved by charring. Oil plants, including flax (*Linum usitatissimum*) and opium poppy (*Papaver somniferum*) were found in very large amounts, as is typical for lakeshore sites (Billamboz et al. 2010; Jacomet et al. 1989; Maier 2001; Maier and Vogt 2004; Rösch 1985). The spectrum of cultivated plants in both phases is very similar, although it seems that naked wheat and flax gain importance in layer 14 (Antolín et al. 2017a). Pulses were underrepresented in the samples of layer 13 due to difficulties during the identification process. Pea (*Pisum sativum*) was identified and it seems to have been an important crop, considering the average densities in layer 14 (ca. 80 r/L). Large seeded wild fruits (such as hazelnuts, acorns, and wild apple/pears) have also been observed to play a very significant role in the economy of the settlement (Antolín et al. 2016, 2017a).

The evaluation of the weeds accompanying crop plants has not yet been done in detail, and further work will focus on the charred layer of stored grain in order to identify charred seeds of weeds. In general, it seems that the weed spectrum is similar to that observed in other Horgen sites and briefly presented above, such as typical winter annuals (*Aphanes arvensis, Valerianella dentata, Cuscuta epilinum* or *Fallopia convolvulus*) and summer annuals (*Arenaria serpyllifolia, Cerastium pumilum, Potentilla argentea, Chenopodium album, Galeopsis tetrahit, Polygonum persicaria* or *Sonchus asper*). This spectrum would not fit with the usual spectrum of burnt fields in a shifting system (Bogaard 2002) but with that of permanent fields, maybe with the use of fallowing (for further details see Antolín et al. (2017a).

Some thoughts about the spatial distribution of the main economic taxa

Interpreting the palaeoeconomic meaning of plant remains, even under the best preservation conditions, is not straightforward. Plant remains may arrive into lakeshore villages through a number of different paths, including construction material, animal dung, etc. Besides, one needs to be sure that the postdepositional processes have not affected either their preservation — in a way that comparisons between different areas or parts of the stratigraphy are not any more possible — or their location at the moment of being discarded — since e.g. wave action could influence their final distribution.

Taphonomic evaluation of plant remains (Antolín et al. 2017a,b), as well as of multiple other proxies (Bleicher, et al. submitted; Bleicher et al. 2017) have shown that the uppermost part of the archaeological layer of ZHOPE had experienced intense erosion in the northern half of the site, and significant reworking due to site abandonment and subsequent natural dynamics in the rest of the site. It was, however, concluded on the basis of several example calculations, that comparisons across the site were only possible if samples from the lowermost part of the layer were used.

The observation of the distribution of certain plant remains should help us to identify areas of cereal processing (observed in the accumulation of chaff remains) or the type of uses of flax (through the observation of the distribution of seeds and capsules (i.e. if the distribution is similar, they could be interpreted as resulting from the production of oil, as stated above). The spatial evaluation of the botanical data (including a detailed comparison between houses) will be done in the future.

We selected some examples of layer 13 at ZHOPE to show the potential of this type of approach (Figure 3): cereal bran, free-threshing cereal chaff, flax seeds and capsule fragments, and seeds of opium poppy. The large accumulations of cereal bran, sometimes within house limits but often close to the edges might indicate grinding areas, since bran is one of the by-products of grinding (see e.g. Alonso et al. 2014). Findings of bread-like objects have been identified at the site (Heiss et al. 2017), which suggests that grinding and baking could have taken place at a household scale. Smaller accumulations of bran could also reflect the presence of dung, since it usually survives digestion. The distribution of the largest accumulations of chaff of free-threshing cereals shows that threshing must have taken place, at least to some extent, in open areas and not inside. Similar interpretations regarding free-threshing wheat were reached at the site of Torwiesen II (Maier and Harwath 2011). Smaller accumulations within loam lenses or rubbish heaps might respond to the use of chaff as animal fodder. Regarding the distribution of flax seeds and capsule fragments, concentrations mainly consisting of seeds were found in several buildings (mostly inside them). This could indicate the consumption of seeds. At the same time, the finding of capsule-rich samples could correspond to observations done in other sites of this period, referring to the use of capsules to gain oil. One also needs to take into account that capsule fragments discarded between buildings could have been accumulated landwards by wave action. Opium poppy seeds were found in very large amounts, particularly within building limits. This latter observation was also similar at Torwiesen II (Maier and Harwath 2011).

For further distribution plans and discussion on the distribution of plant remains see Antolín et al. (2017a).

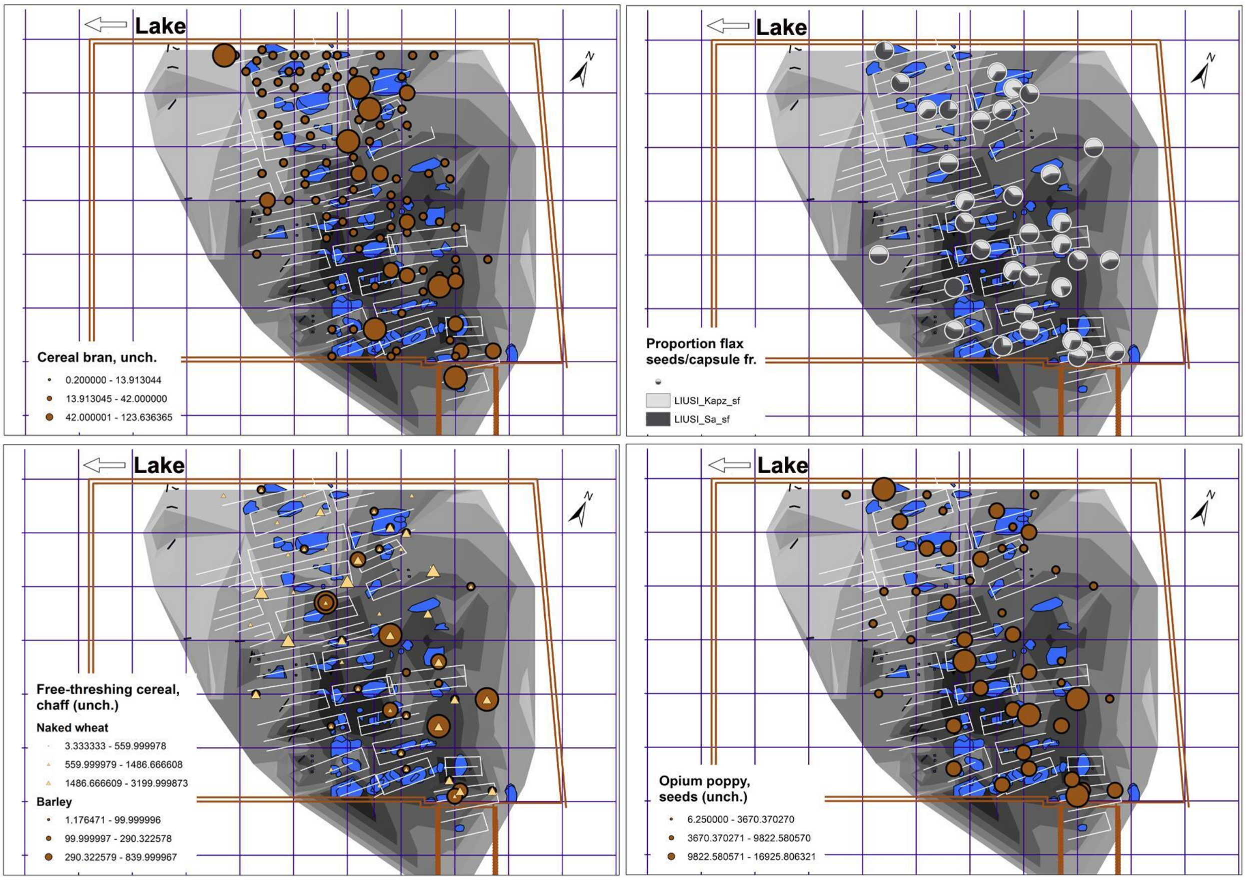


Figure 3: Site plans of ZHOPE showing the density of plant remains obtained per sample. Only samples at the base of the stratigraphy have been represented to allow a more direct comparison across the site's surface. The scale of greys in the background indicates layer thickness (from ca. 5 in the lightest spots to ca. 30 cm in the darkest ones). Areas in blue indicate loamy sediment, which is well connected with the groundplans of the houses.

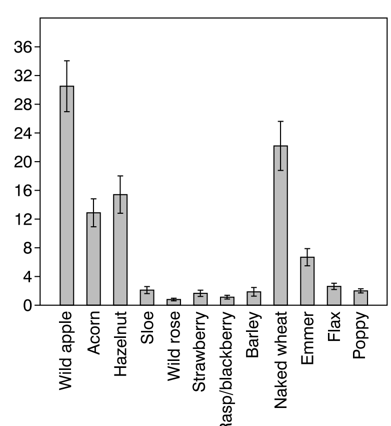


Figure 4: Barcharts showing the mean and standard error obtained from the proportion of calories represented by each ressource in each of the 53 samples located at the basis of the stratigraphy of ZHOPE.

Towards a diet reconstruction at a site scale in ZHOPE

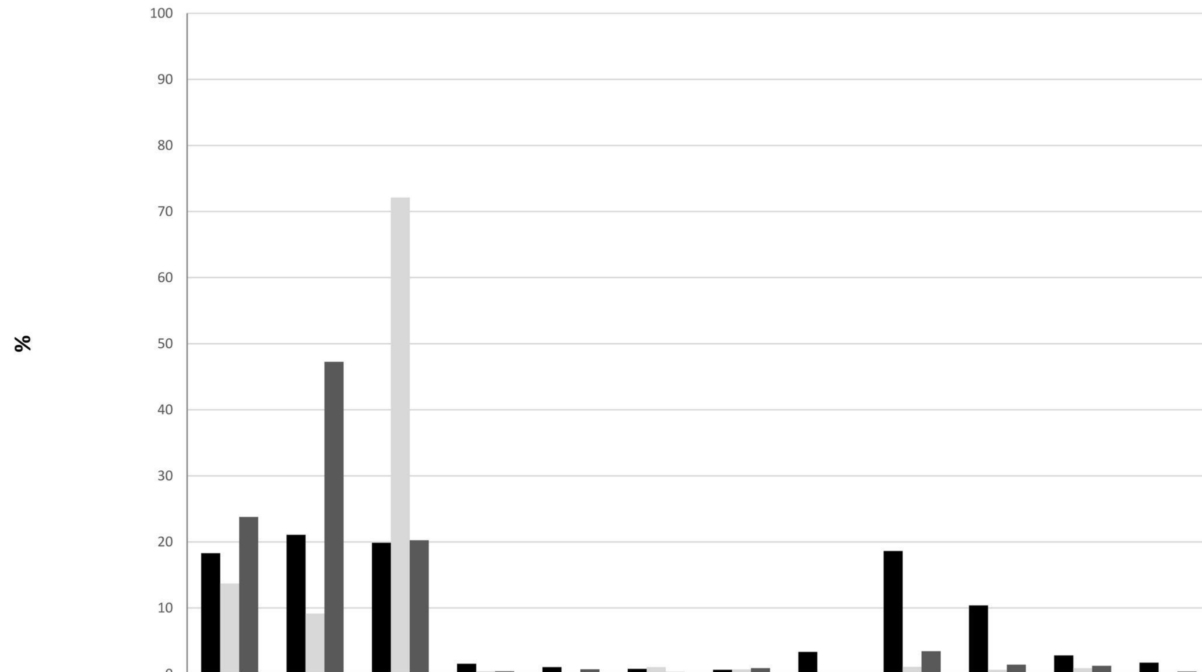
The quantification units used in archaeobotany do not always directly allow the quantification of the minimum number of seeds/fruits in a sample. This would be useful as a basis to infer weight and calories, with the limitations that we need to take into account (we do not have references for the weight of prehistoric wild apples, for instance). This, together with the diverse taphonomic processes that affect plant remains in most dry sites, usually results in a very limited (or mostly absent) approach to the diet (the relative contribution of cereals, legumes, oil plants, and wild plants to the diet) of the inhabitants of the studied sites. Only in wet sites can one assume that uncharred plant remains (particularly those found in greater abundance) are a more or less reliable proxy for consumed plant resources. Most of the previous attempts on this field are therefore only found in the Alpine Foreland.

At ZHOPE, plant remains are quantified in a manner that they roughly express a minimum number of individuals (MNI) in most cases. In other cases, easy formulas can be applied to calculate the minimum number of fruits (e.g. apple pericarps/10= 1 apple). There are formulas to calculate MNI for different taxa (Antolín and Buxó 2011; Antolín and Jacomet 2015;

Berihuete and Antolín 2012), but they are time-consuming and mostly proposed for charred assemblages, where the time investment is significantly lower than in wetland sites. We can in any case present an approach to human diet at layer 13 in ZHOPE on the basis of the 53 samples that were completely analysed (A- and B-samples of the same master sample) and that were located at the basis of the stratigraphy, thus presenting optimal preservation conditions. The values used for the calculations are presented in Table 2 and obtained from several bibliographical sources (Antolín et al. 2016, and references therein; Elmadfa et al. 2014; Kuhnlein et al. 2006). It is clearly observed that wild resources add up to about 65 per cent of the total calorific input, while domestic resources (cereals and oil plants) add up to 35 per cent (cereals yielding most of it, around 30 per cent of the calories) (Figure 4). One should still add the role of legumes (green pea). This was done on a theoretical basis, using the data from layer 14 of ZHOPE, where the pea pod fragments of peas were correctly identified and quantified. Considering that pea pods were found in an average density of 81.1 r/L, and that each pea weights about 0.15 gr and has ca. 0.84 calories/gr, one would obtain an average hypothetical percentage of 1.2 per cent of the total calories represented. It is not a neglectable amount, since peas are particularly important due to their high protein content and particularly as a daily complement to cereals in order to allow the absorption of those proteins (e.g. Rosenstock et al. 2015, and references therein). In any case, it does not change the general picture: wild plants contributed with a major role to everyday diet at Parkhaus Opéra. It is also possible that the large number of unidentified cereal chaff might reduce the representation of cereals in the graph. If we increased the calorific contribution of cereals in 1/3, which is a common proportion of unidentified cereal chaff in most samples, the overall calorific contribution of cereals in the diet would be ca. 38–40 per cent, while gathered plants would add up to ca. 57 per cent of the total calorific input. These results are similar to those obtained at Arbon Bleiche 3 (Hosch and Jacomet 2004).

Is this a single case in lakeshore settlements? Due to inappropriate sampling strategies (too few samples of a low volume, much below 1 L in average), we cannot compare our data with many other sites dating to the second half of the 4th millennium cal. BC, but we can compare them with Arbon Bleiche 3 and Horgen Scheller, Layer 3 (probably a seasonal site where wild resources make the greatest part of the archaeobotanical and archaeozoological record). The results show that, if anything, the results of ZHOPE are the ones that allow a better representation of cultivated plants in the diet (Figure 5). In front of these results, one can only wonder if cultivated plants could be underrepresented in our records, which would be completely unexpected given the fact that the spatial distribution of these remains shows the regular practice of household processing. In our opinion, current results indicate that the role of wild plants in the diet of early farming populations is regularly underestimated and that too much focus had been put on the importance of cultivated plants, which make up a very significant part of the diet, but not the largest amount, when one considers the calorific input. Further discussion could follow on the significance of each of the resources in each site, but this is not the aim of this paper.

When looking at the significance of wild plant gathering in the economy of ethnographical case studies in the *Ethnographic atlas* of Murdock (see a



	Wild apple/pear	Acorn	Hazelnut	Sloe	Wild rose	Strawberry	Rasp-/Blackberry	Barley	Naked wheat	Emmer	Flax	Poppy
ZHOPE	18.3	21.1	19.9	1.5	1.0	0.8	0.6	3.3	18.6	10.4	2.8	1.7
Arbon Bleiche 3	13.7	9.1	72.1	0.4	0.2	1.0	0.7	0.1	1.1	0.6	0.9	0.1
Horgen Scheller, Layer 3	23.8	47.2	20.2	0.4	0.7	0.3	0.9	0.0	3.4	1.4	1.2	0.4

Figure 5: Percentages of calories obtained from each plant food resource at ZHOPE, Arbon Bleiche 3 and Horgen Scheller. For the calculations, the same values presented in Table 2 were used.

synthesis in Antolín and Berihuete 2017, and references therein) it seems a rare case that a farming population puts such a big effort in wild plant gathering. Such a case is more often found in small-scale societies with a low social stratification where agriculture (either intensive or shifting agriculture) does not play a preponderant role in the economy (Antolín and Berihuete 2017). It is therefore of major interest to pursue further this line of research.

Table 2: General results of layer 13 in ZHOPE with the main taxa recovered in the archaeobotanical record presented in average density of the MNI (53 completely analysed samples from the basis of the stratigraphy were used), with additional information on the weight per seed/fruit, calories per gram and the overall resulting calories per taxon, as well as the percentage of the total amount of calories and the corrected percentage when taking unidentified cereal chaff into account as mentioned in the text (see references in the text and in Antolín et al. 2016).

	Average density (MNI)	**Weight per seed/fruit (gr)**	**Calories/gr**	**Total calories**	**per cent of the total calories**	***corrected per cent of the total calories**
Wild apple/pear	10.3	20	0.76	156.5	18.3	16.5
Acorn	13.0	6.33	2.191.6	180.2	21.1	19.0
Hazelnut	26.4	1	6.44	169.9	19.9	17.9
Sloe	3.9	7	0.48	13.2	1.5	1.4
Wild rose	5.4	3	0.55	8.8	1.0	0.9
Strawberry	12.1	1	0.54	6.5	0.8	0.7
Rasp-/Blackberry	9.4	1.3	0.44	5.4	0.6	0.6
Barley	356.6	0.023	3.48	28.5	3.3	4.0
Naked wheat	1953.1	0.027	3.02	159.3	18.6	22.4
Emmer	1223.1	0.024	3.02	88.6	10.4	12.6
Flax	1279.8	0.005	3.76	24.1	2.8	2.5
Poppy	5129.0	0.0006	4.77	14.7	1.7	1.6

Conclusions

Recent research at Zürich-Parkhaus Opéra proved that archaeobotanical investigations in lakeshore settlements can still (after intensive research in the past decades) bring important information about prehistoric communities living on the shores of the lakes found north of the Alps, if the full potential is used employing latest methodologies. It was shown how the latest methodological improvements, following previous developments, increase the representativeness and comparability of the data produced and how it has been possible to better document some important plant resources, particularly those of most fragile nature, but also large-seeded wild plants.

Having produced high-quality data for the site, and after having done the necessary taphonomic research for establishing the representativeness of the data across the stratigraphy and the site's surface, it will now be possible to move forward to largely unexplored areas of research such as diet. It is our hope to be able to start defining household units (with integrative methods) and later characterise their economy and nutrition in a more detailed way than ever before in the past.

Acknowledgements

This study was funded by the Swiss National Science Foundation, project number CR30I2_149679/1 (main project leader Philippe Rentzel) and the canton and town of Zürich.

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Archaeological and palaeoecological investigations at Burgäschisee (Swiss Plateau): new interdisciplinary insights in Neolithic settlement, land use and vegetation dynamics

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Introduction

The prehistoric lake dwellings of Switzerland, Germany, and Austria have been known for more than 150 years. Of these, 111 were awarded UNESCO World Cultural Heritage status in 2011. Mainly dating from the Neolithic (including the Chalcolithic or Copper Age) and the Bronze Age, lacustrine settlements represent an early phase of sedentarisation in the northern foothills of the Alps. Despite much significant research on the material culture, settlement dynamics, economy, and ecology, the focus has hitherto almost exclusively been on the classic sites situated on the larger northern pre-Alpine lakes in the so-called Three Lakes region of western Switzerland and on the Lakes of Geneva, Zurich, and Constance. The international and interdisciplinary research project 'Beyond lake villages: studying Neolithic environmental changes and human impact on small lakes in Switzerland, Germany and Austria' was launched in 2015

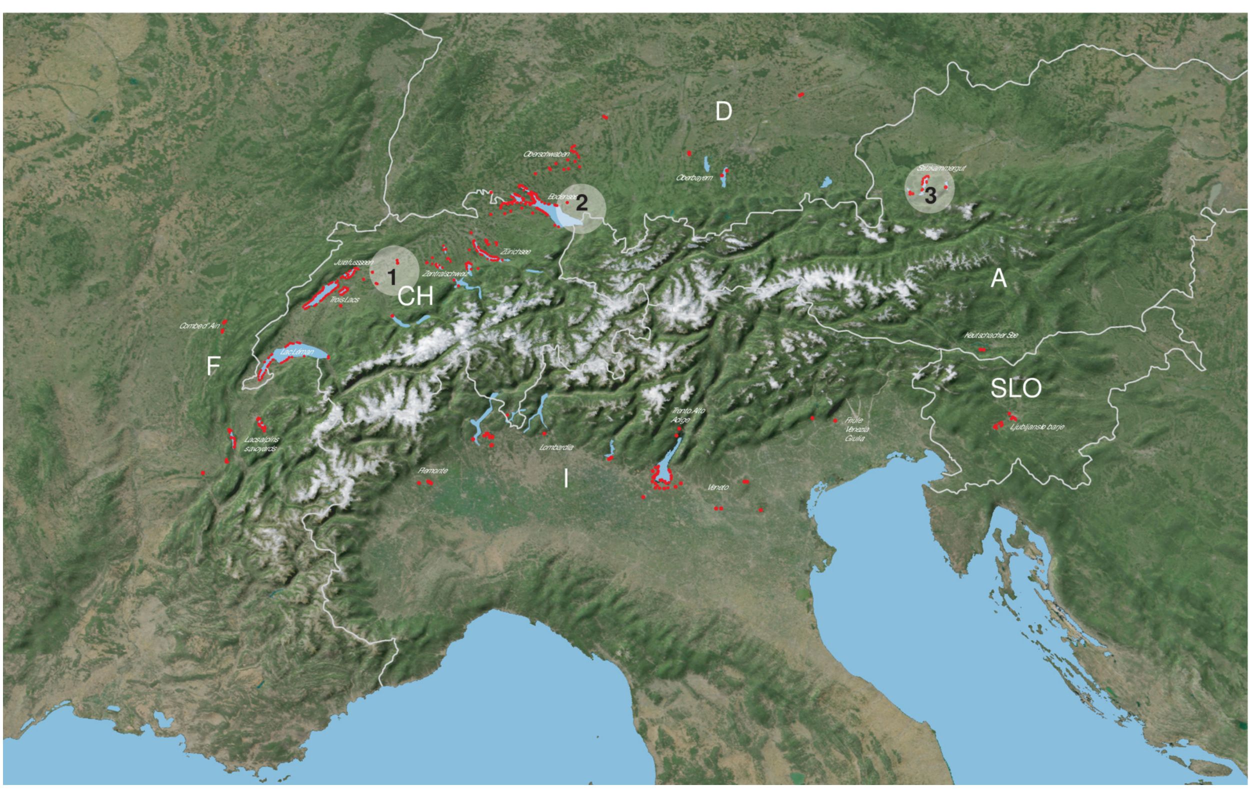

Figure 1: Areas examined as part of the interdisciplinary project entitled 'Beyond lake villages' in the Alpine region. 1 Burgäschisee, central Switzerland, 2 Westallgäu, southern Germany, 3 Salzkammergut, Austria.

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and is jointly funded by the Swiss (SNF), German (DFG), and Austrian (FWF) National Science Foundations. Research teams in prehistoric archaeology and palaeoecology from the universities of Bern, Basel, Vienna, and Innsbruck as well as the cultural heritage management authorities of the German State of Baden-Württemberg and the Swiss Cantons of Bern and Solothurn are concentrating their efforts on three Neolithic settlement areas on the Swiss Plateau, the German Westallgäu, and the Austrian Salzkammergut (Figure 1). Research is focused on small, deep lakes and their immediate surroundings, with the aim of obtaining new high-resolution data on the natural environment and human impact on the landscape. Our ongoing palaeoecological investigations have confirmed that small, deep lakes such as Burgäschisee and Moossee in Switzerland preserve laminated annual sediments that have enormous potential for generating high-resolution, diachronic data on vegetation, palaeoclimate, and human impact. Through the integration of wetland archaeology and palaeoecology, we hope to generate new data and models that will help to understand the variability of human impact on landscapes, especially the environmental interactions of Neolithic societies in the circum-Alpine region. The overall aim of the project is to gain a better understanding of large-scale processes of adaptation and anthropogenic impact over time. The 'Beyond lake villages' project began by setting the following goals:

- to significantly enhance the archaeological database of Holocene human activity in three research areas and to precisely analyse chronologically-resolved sedimentary records (e.g. pollen, spores, macrofossils) of annually laminated sediments, and to cross-correlate them with phases of occupation as dated by dendrochronology and AMS-radiocarbon chronology in periods of significant palaeoclimatic oscillations.
- to expand research into the 'hinterland' of large pre-Alpine lakes to examine an extended range of human land use activities employing a combination of archaeological and palaeoecological methods so as to identify and understand the nature of agricultural systems, fire management regimes, wildfires, and woodland cycles.
- to gauge population mobility and to establish patterns of demographic change.
- to identify agents of economic and cultural processes in relation to physical-geographical conditions and human economic adaptions at a time of significant climatic/environmental change and to model possible scenarios across three similar cultural and natural environments in the northern pre-Alpine zone.

Geographical data and earlier research

Burgäschisee is a small eutrophic lake on the Swiss Plateau (47°10'8.5"N, 7°40'5.9"E) located at 465 m a.s.l. (Figure 2, Figure 3). The surface area is 21 ha, the maximum water depth is 31 m and the hydrological catchment area is 3.2 km^2 (Guthruf et al. 1999). Ca. 18,500 years ago, after the end of the Last Glacial Maximum (LGM), its surface area was about six times larger than it is today (von Burg et al. 2011). During the Holocene, the shallow areas of the Pleistocene lake transformed into large peat bogs. The lake level was artificially lowered by 2 m in 1943 to drain the wetlands

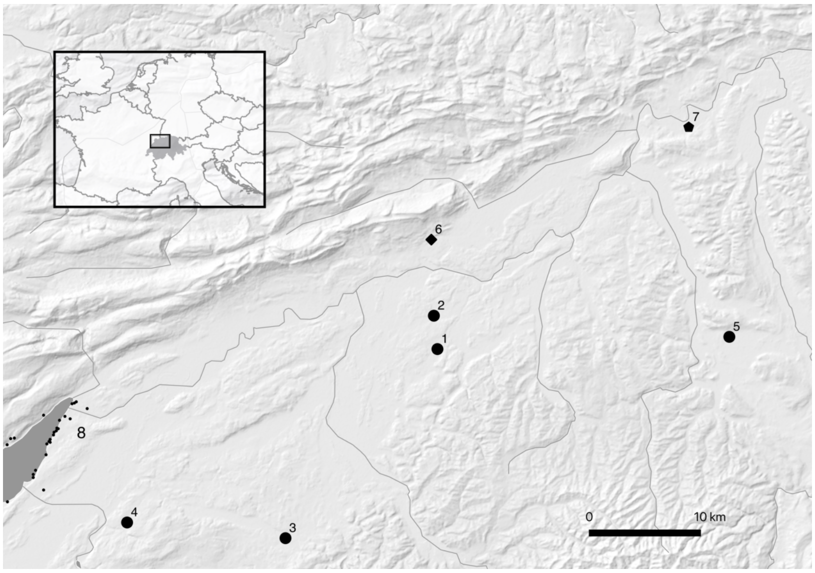

Figure 2: The Burgäschisee research area in central Switzerland and associated Neolithic sites. 1 Burgäschisee, lake dwellings, 2 Inkwilersee, lake dwellings, 3 Moossee, lake dwellings, 4 Lobsigensee, lake dwellings, 5 Egolzwil, lake dwellings, 6 Oberbipp, Steingasse, collective dolmen burial site, 7 Däniken, Studenweid, stone cist burial site, 8 Lake of Biel, lake dwellings.

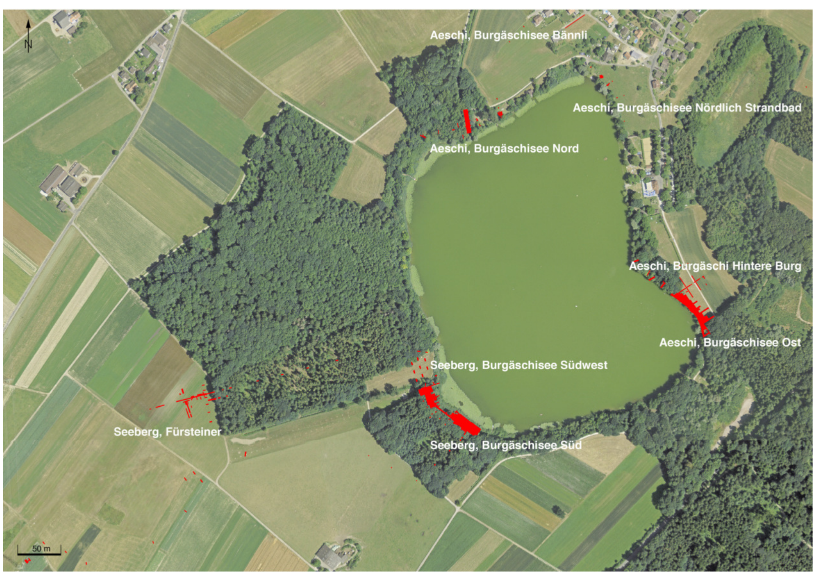

Figure 3: Aeschi SO and Seeberg BE. Burgäschisee. Archaeological investigations.

in the area and to create farmland (Arn 1945). The local climate is oceanic with a mean annual temperature of 9.1 °C and an annual rainfall average of 1088 mm (data: MeteoSwiss).

The first archaeological finds came to light in the mid-19th century. Surface concentrations of flint artefacts along the Pleistocene/Early Holocene shorelines point to the presence of hunter-gatherer camps which can be attributed to the Magdalenian and Late Palaeolithic and to the Mesolithic (von Burg et al. 2011; Wyss 1952, 1953). Excavations at Neolithic settlement sites began in 1877/1902 and were followed by several major excavation campaigns in 1944–1946, 1951–1952, and 1957–1958 (Anliker et al. 2009, 2010; Bandi et al. 1973; Bleuer et al. 1988; Brunnacker 1967; Müller-Beck and Schweingruber 1965; Müller-Beck and Wey 2008; Wey 1999, 2001, 2012). Before the 2015–2017 investigations, four Neolithic settlements from the 4th millennium BC had been known and individual finds had also indicated human presence during the 5th and 3rd millennia BC. Several inhumations, probably Neolithic cist graves, were found in the early 20th century in bogs immediately west of Burgäschisee. Similar cists dating from around 4300–4000 BC were found in 1946 and 1970 at Däniken, Studenweid, approximately 10–20 km away (Dubuis and Osterwalder 1972; Schweizer 1947). A collective burial in a megalithic dolmen dating from 3300–3000 BC was discovered in 2012 at Oberbipp, Steingasse (Ramstein et al. 2013). Bronze Age finds indicating 2nd millennium BC settlements were detected in nearby Lake Inkwilersee (3 km from Burgäschisee) during underwater archaeological surveys carried out in 2007 (Hafner and Harb 2008; Hafner et al. 2008), altogether suggesting that the area was permanently settled since more than 6000 years.

The Burgäschisee area is situated between the important Neolithic settlement concentrations in the Three Lakes region (Seeland) in the west and Lake Zurich in the east. Because the excavations at Burgäschisee took place early in the history of archaeological research, only a small number of dendrochronological dates were available from one of the sites until now. A predominance of Cortaillod-style pottery suggests contact between Burgäschisee and western Switzerland on one hand and 4th millennium sites in the Three Lakes region and beyond (Néolithique Moyen Bourguignon pottery styles in eastern France) on the other. Copper artefacts and crucibles found at Burgäschisee also indicate intensive long-distance contact with areas in eastern Switzerland and southern Germany (Anliker et al. 2010; Dzbyński 2014; Lefranc et al. 2012; Nielsen 2012; Ottaway and Strahm 1975; Wey 2012) whilst unique animal clay figures of Neolithic age suggest cultural links with regions even further to the east (eastern Austria, Moravia, and Bohemia).

Pioneering palynologist Max Welten examined lakeshore sediments and an on-site palynological transect through one of the prehistoric settlements from the 1940s onwards. In this way he was able to reconstruct the vegetation for a period of over 15,000 years; an extraordinary feat for the time (Welten 1947, 1955, 1967). From 2009 to 2014, exploratory studies initiated by the Palaeoecology Group at the Institute of Plant Sciences and the Oeschger Centre for Climate Change Research at the University of Bern, in collaboration with the Climate Geology Group at the Swiss Federal Institute of Technology ETH in Zurich, made it possible to identify the Burgäschisee region as a new archive of annually laminated sediments. The area has a very limited catchment and no relevant slopes, resulting in negligible erosional input (van Raden et al. 2013). In the autumn of 2009 and spring of 2014, a total of four parallel sediment cores (up to 15 m long) were retrieved from the deepest point using an UWITEC piston corer. Radiocarbon dates and palaeoecological data showed that the lake sediments cover a period of at least 18,700 years (Rey et al. 2017). These overall investigations suggested similar vegetation and land use dynamics for the Burgäschisee region as those identified at other (partially annually laminated) sites on the Swiss Plateau (e.g. Soppensee, Lotter 1999), where the vegetation dynamics (e.g. vegetation composition, openings of forests) were mainly controlled by land use measures including the use of fire since the beginning of the Neolithic around 5400 BC (Tinner et al. 2005a, 2003). They also suggested that thanks to the annual laminations from the mid and late Holocene, Burgäschisee could be one of only a few lakes on the Swiss Plateau that is suitable for high-precision and high-resolution palaeoecological studies (Rey et al. 2017).

Archaeological investigations: new data from Neolithic settlement sites

The last large-scale excavations carried out on Burgäschisee from 1952 to 1958 were run by the Historisches Museum Bern and the Institute ('Seminar') of Prehistory at the University of Bern (predecessor of today's Institute of Archaeological Sciences, both of which were managed by Hans-Georg Bandi at the time). Following ground-breaking early interdisciplinary research, Burgäschisee fell into a deep slumber for over 50 years and no synthesis of the prehistoric occupation of this small settlement area, which was one of the most important settings for pile-dwelling research for more than 150 years, was ever compiled. From the point of view of archaeological research, the lack of dates obtained by modern methods made it impossible to compile an overview of the well-known sites and the settlement history of the Burgäschisee region. Because the locality also bore a high palaeoecological potential for varve formation, the Institute of Plant Sciences at the University of Bern independently carried out sediment coring at Burgäschisee in 2009 and again in 2014. The combination of all these aspects led to a situation that appeared to be suitable for a joint archaeological and palaeoecological research project, and initial archaeological preparation work began in 2012. In the summer of 2013, various archaeologically promising areas were surveyed by means of an intensive coring programme. All areas with wetland preservation near the shoreline of Burgäschisee and in the adjacent wetland areas of Aeschimoos and Chlöpfibeerimoos were examined using hand augers. This led to the discovery of a number of previously unknown Neolithic settlements and helped to define more precisely the boundaries of known settlement sites. On the other hand, the almost 200 cores also showed that there were no prehistoric settlement layers in the peatlands of Chlöpfibeerimoos or Aeschimoos areas. Additional surveys were undertaken further away from the lakeshore on slightly elevated areas without wetland preservation at Aeschi SO, Burgäschi, Hintere Burg, and Bännli and at Niederönz SO, Seeacher, and Seeberg BE, Seematt, and these were combined with data obtained from 2015 to 2016. Only Burgäschi, Hintere Burg was revealed to be an area of archaeological interest, the other examinations produced negative results.

Whilst hydrographic investigations carried out in December 2014 in the shallow water zone of Burgäschisee using a single-beam echo sounder had indicated archaeologically promising areas, a coring survey to test these areas produced no positive results. The entire shallow-water area of Burgäschisee was examined in March 2016 by members of the diving team of the Archaeological Service of Canton Bern, but no evidence of submerged settlements, such as piles or pottery, were discovered on the lakebed. The underwater archaeological surveys were hampered by difficult conditions in the lake, where a high concentration of suspended matter generally restricted the divers' visibility to less than 1 m. The reed beds in the shallow-water areas on the northern and southern shores as well as dense macrophyte cover along the western shore further impeded surveying of the lakebed.

Between 2015 and 2017, numerous test excavations were carried out at the lakeshore sites of Seeberg BE, Burgäschisee Süd and Südwest, and Aeschi SO, Burgäschisee, Nord, Nördlich Strandbad, Ost and Hintere Burg and were extended to areas of up to 30 m^2 if the test trenches had yielded

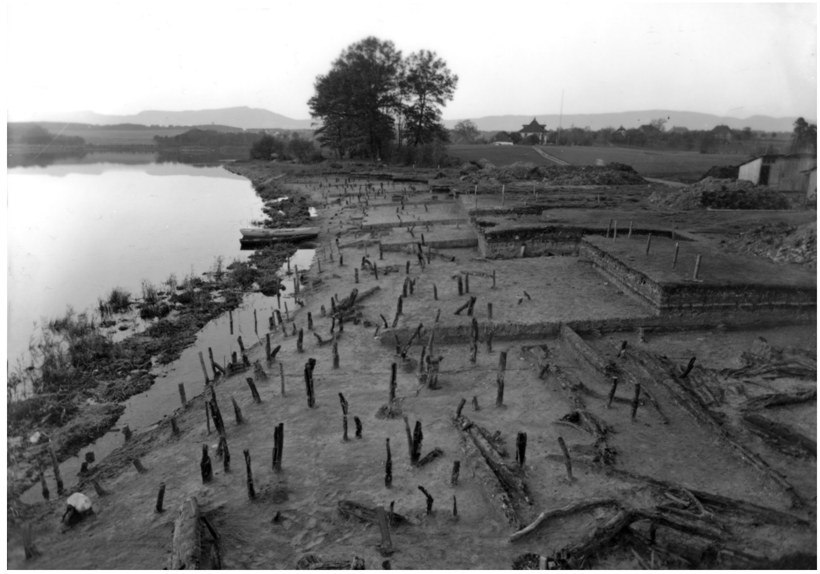

Figure 4: Aeschi SO, Burgäschisee Ost. Overview of the Neolithic pilefield uncovered by the 1944 excavations.

Figure 5: Aeschi SO, Burgäschisee Ost. Working situation 1944 excavations.

any positive results (local excavation director: Othmar Wey). Test trenches were dug both at known sites and in areas that had not yet yielded any archaeological evidence but which appeared promising. Because the known sites were all excavated between 1877 and 1958 and the excavation records had either been partially or completely lost, leaving considerable gaps in the available information, the test excavations mainly aimed to obtain evidence with regard to the stratigraphical sequence and to retrieve piles and horizontal timbers for dendrochronological dating. A total of six settlement sites, some multi-phased and considerable in size, are now known to have existed at Burgäschisee during the Neolithic period.

Figure 6: Aeschi SO, Burgäschisee Ost. Reconstruction of house locations based on a plan from the 1944 excavations.

Aeschi SO, Burgäschisee Ost

The site of Burgäschisee Ost was excavated in detail in 1944–1945 after the lake level had been artificially lowered (Figure 4, Figure 5). The excavation revealed a large but rather sparse pilefield and a thin layer, most probably disturbed, containing archaeological finds. Ceramic vessels of the classical Cortaillod style allowed us to date the site to around 3800 BC (Anliker et al. 2009, 2010). The closest parallels were the pottery assemblages from Twann BE, Bahnhof, US layer (Lake Bienne, 40 km west of Burgäschisee, dendrochronologically dated to 3838–3768 BC; Stöckli 1981, 2009), Egolzwil 2, layer III, and Egolzwil 4 (both at the Wauwil bog, 30 km east of Burgäschisee; Wey, 2001). Two piles recovered from the area were dendrochronologically dated in 1985 (Anliker et al. 2009). The waney edge dates were estimated to have covered the period between 3835–3830 BC. The dates were based on a short mean curve of only 35 tree rings and the original readings and samples have since been lost. It is not possible, for the time being, to confirm these dates, although they do correspond with the typological dating of the site. Several ceramic finds typical of the Egolzwil style, the most important sites being Egolzwil LU, Egolzwil 3, dendrochronologically dated to 4280 – 4250 BC (De Capitani and Seifert 2013), and Zürich, Kleiner Hafner, layer 5, (Suter 1987), suggest settlement activity in the late 5th millennium BC. A single fragment of a typical Corded Ware pot with a wavy cordon indicates that people were present in the area in the early 3rd millennium BC (c. 2800–2600 BC) but remains difficult to interpret since no other material from the period was found. A few flint artefacts from layers beneath the Neolithic horizon of Burgäschisee Ost may date to the Magdalenian period (c. 14’000–13’000 BP) or the Late Mousterian period (c. 35’000 BP Anliker et al. 2009). Two new trenches measuring 30 m^2 and 35 m^2 were examined within the area that had been excavated in 1944. Unfortunately, most of the wooden piles had not survived because the water table had been quite low over an extended period of time. Therefore, only two piles, one from each trench, could be sampled. A thorough analysis of the existing plans using a GIS and separating oak from non-oak timbers allowed us to newly interpret and reconstruct the ground-plans of the houses (Figure 6). Ten buildings with three rows of posts and dimensions of up to 9 m in length and 4–5 m in width were reliably reconstructed. The settlement layout consisting of parallel houses set at right angles to the lakeshore has also been identified at several other settlements dating from the first half of the 4th millennium in the Wauwil area (Egolzwil 4 and 5) and in the Three Lakes region (Lake Bienne: Sutz-Lattrigen, Hauptstation Innen, Lake Neuchâtel: Hauterive, Champréveyres).

Aeschi SO, Burgäschisee Nord

The site of Burgäschisee Nord was first excavated in 1877, and then in 1902 and again in 1943 and 1945 (Figure 7). In contrast, to the excavations at Burgäschisee Ost in 1944–1945 the Burgäschisee Nord activities were not well documented, and their precise location is unknown. Ceramic finds from these early archaeological activities point to the existence of human settlements in the early and mid-4th millennium (classical and late Cortaillod Style, dating from around 3900 to 3600 BC) and in the early 3rd millennium BC (Corded Ware pottery; Wey 1999/2001). The excavations in 2015–2016 (Figure 8) at Burgäschisee mainly concentrated on gaining new stratigraphical and dendrochronological data from the site at Burgäschisee Nord, where the majority of the project’s trenches were located. Ceramic finds of classical Cortaillod Style recovered from layer 5.3 in trench 1 confirmed the results obtained from previous, 20th century excavations. The discovery of a large quantity of so-called scratched or incised pottery (Figure 9) (layer 3, trenches 4, 6, and 10) in western Switzerland was both novel and surprising. This type of Neolithic pottery is not completely unknown but is not usually found outside of the areas with typical Pfyn Style ceramics of eastern Switzerland (e.g. Lake Zurich and Lake Constance, Figure 10–Figure 11) as shown in Figure 12. West of these areas, only a few scratched or incised sherds have been found at Meisterschwanden, Erlenhölzli (Lake Hallwil in central Switzerland), and a single vessel came to light at Burgäschisee, Süd (Bleuer et al. 1988, Fig. 7), though this attracted very little attention at the time. The discovery of such a large assemblage of scratched or incised pottery

Figure 7: Aeschi SO, Burgäschisee Nord. Impressions from the 1902 excavation.

sheds new light on cultural influences from the eastern part of the Swiss Plateau towards the west. Further research on this topic will be required to explain the presence of typical Pfyn style pottery in an area which was previously known only for its western, Cortaillod pottery styles. An initial literature overview suggests that the scratched or incised pottery from Burgäschisee, Nord dates from approximately 3750–3600 BC. Comparable, firmly dated finds are known from Canton Thurgau, south of Lake Constance, at Thayngen, Weier, dated to 3800–3750 BC, (Stöckli 2009, Pl. 58.2), Pfyn, Breitenloo, dendrochronologically dated to 3706–3704 BC (Leuzinger and Haas 2007, Fig. 76 and Pl. 187.3–4), and Ürschhausen TG, Nussbaumersee, Inseli, lower layer, dendrochronologically dated to 3732–3704 BC, (Stöckli 2009, Pl. 63.7-10). The site of Zürich, Mozartstrasse, layer 4u, dendrochronologically dated to 3612–3601 BC, must also be mentioned in this context (Gross et al. 1992).

The 2015–2017 investigations at Burgäschisee produced some 500 samples of wooden piles (dendrochronological analysis: Matthias Bol-

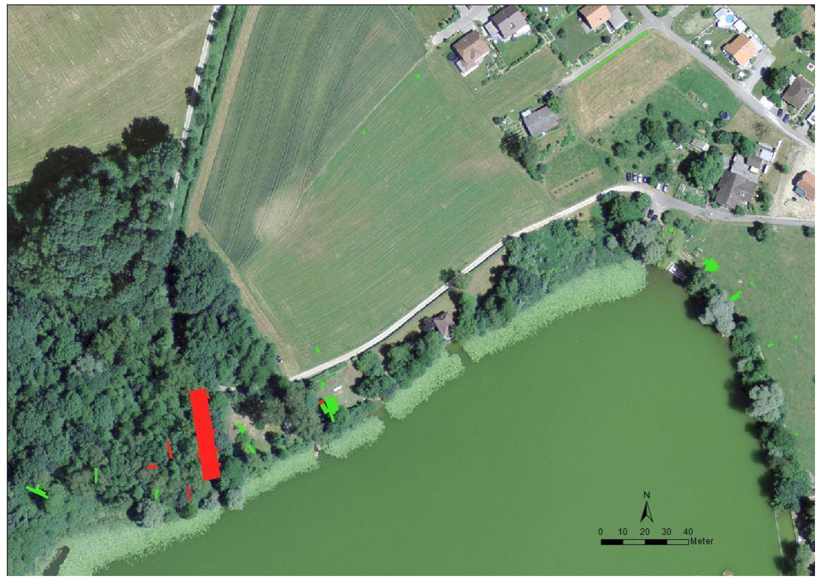

Figure 8: Aeschi SO, Burgäschisee Nord (below) and Nördlich Strandbad (above). Excavated areas. In red: 1944–1945 excavations, in green: 2015–2017 investigations.

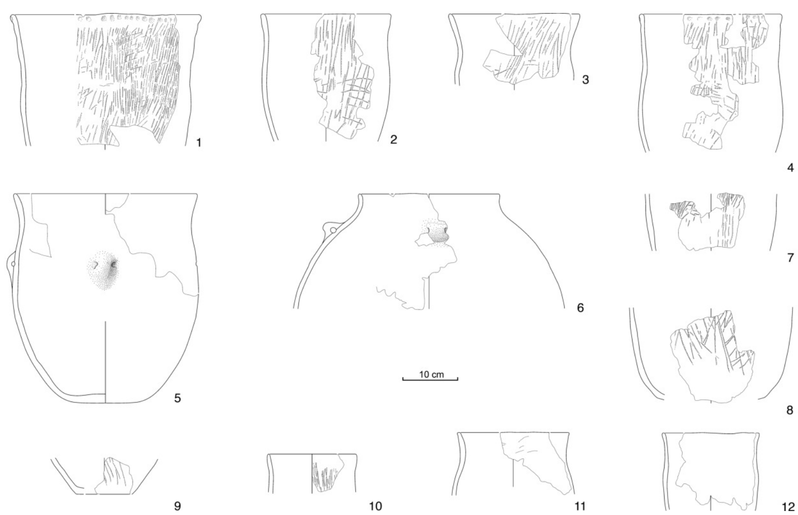

Figure 9: Aeschi SO, Burgäschisee Nord. Scratched or incised pottery (Pfyn style) from layer 3 in trenches 4, 6, and 10.

liger). Unfortunately, most were samples of species not suitable for dendrochronological dating or oak samples with less than 30 tree rings. Previous research had resulted in a local curve for the period between 3976 and 3748 BC (MK 60333 Burgäschisee based on 16 samples from Burgäschisee, Süd and Südwest, established by Bruno Huber in 1967 and tested by John Francuz in 2012). Two samples from Burgäschisee Nord, nos. 48794 and 48772, match the new mean curve, MK 6, with an end date of 3920 BC (heart wood) which could have been associated with, or at least provide a terminus post quem for the earliest settlement phase (Figure 13). A new mean curve, MK 5, was obtained from three samples and covers a settlement phase dating from around 3835–3830 BC (nos. 48773, 48770 and 48768; sapwood). One sample, no. 48771 (waney edge) is dated to 3781 BC and points to a next settlement phase. These preliminary results indicate the possibility of contemporary settlement phases on Burgäschisee in the areas Nord and Ost and Süd and Südwest, respectively.

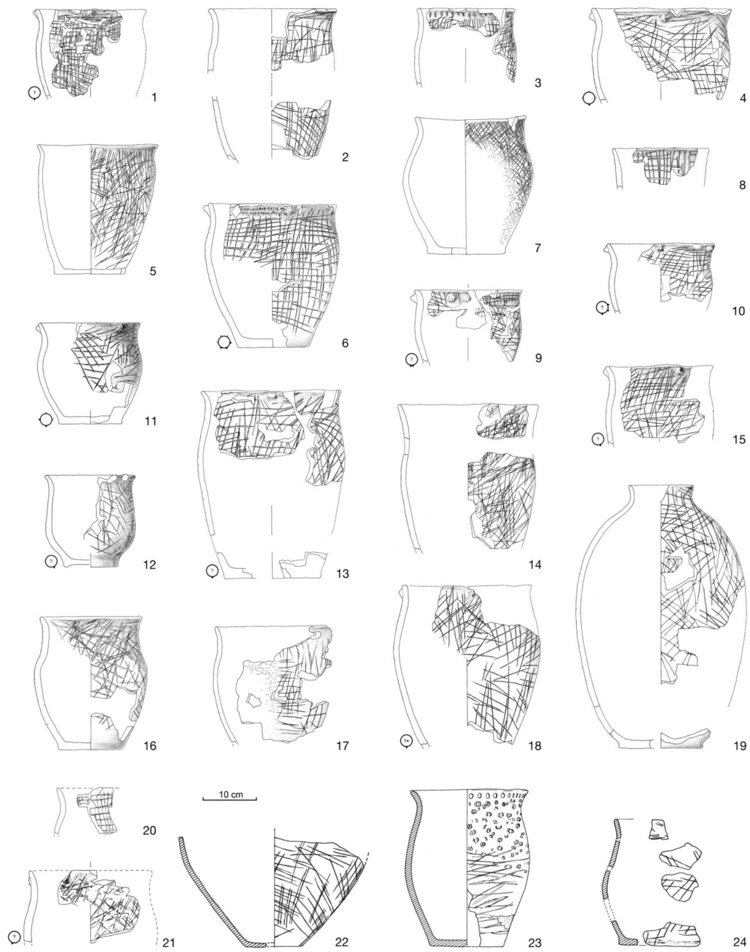

Figure 10: Scratched or incised pottery (Pfyn style) from sites in the Lake Zurich area.

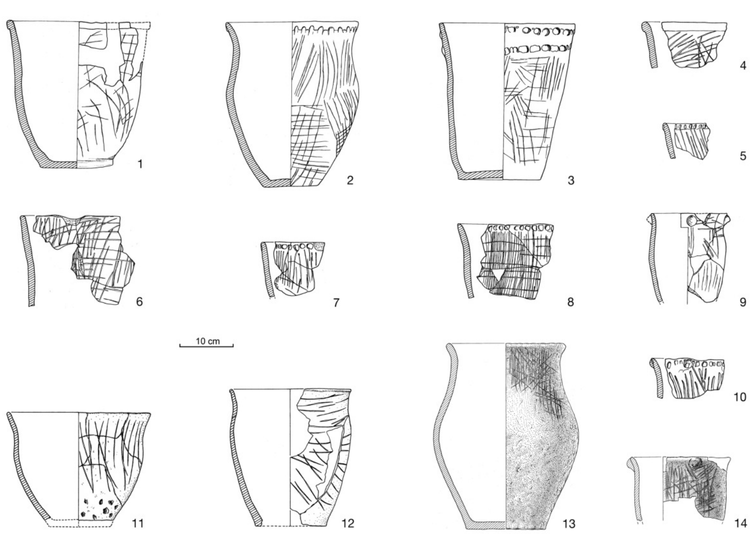

Figure 11: Scratched or incised pottery (Pfyn style) from sites in the Lake Constance area.

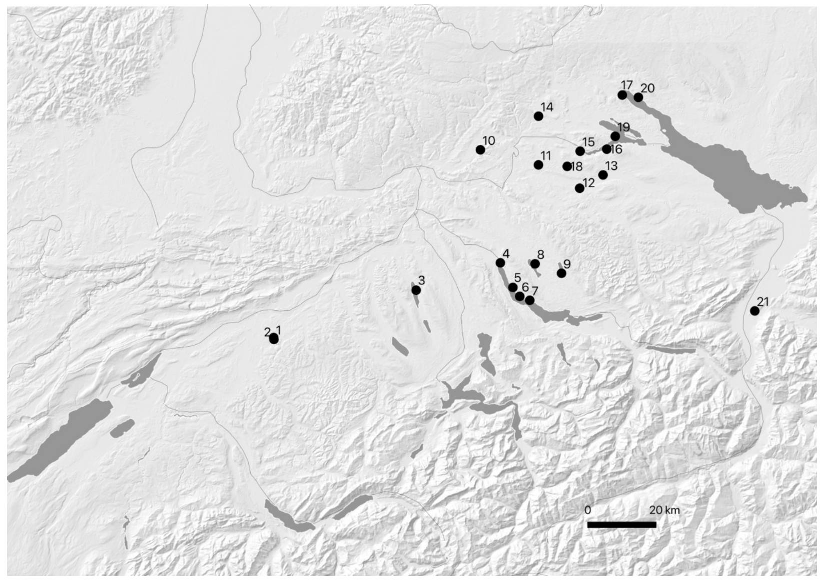

Figure 12: Neolithic lake-dwelling sites with scratched or incised pottery (Pfyn style) in Switzerland and southern Germany dating from 3800–3600 BC.1 Seeberg, 2 Aeschi, 3 Meisterschwanden, 4 Zürich, 5 Erlenbach, 6 Feldmeilen, 7 Obermeilen, 8 Greifensee, 9 Wetzikon, 10 Wilchingen, 11 Ossingen, 12 Niederwil, 13 Pfyn, 14 Thayingen, 15 Eschenz, 16 Steckborn, 17 Bodman, 18 Uerschhausen, 19 Hornstaad, 20 Sipplingen, 21 Gamprin.

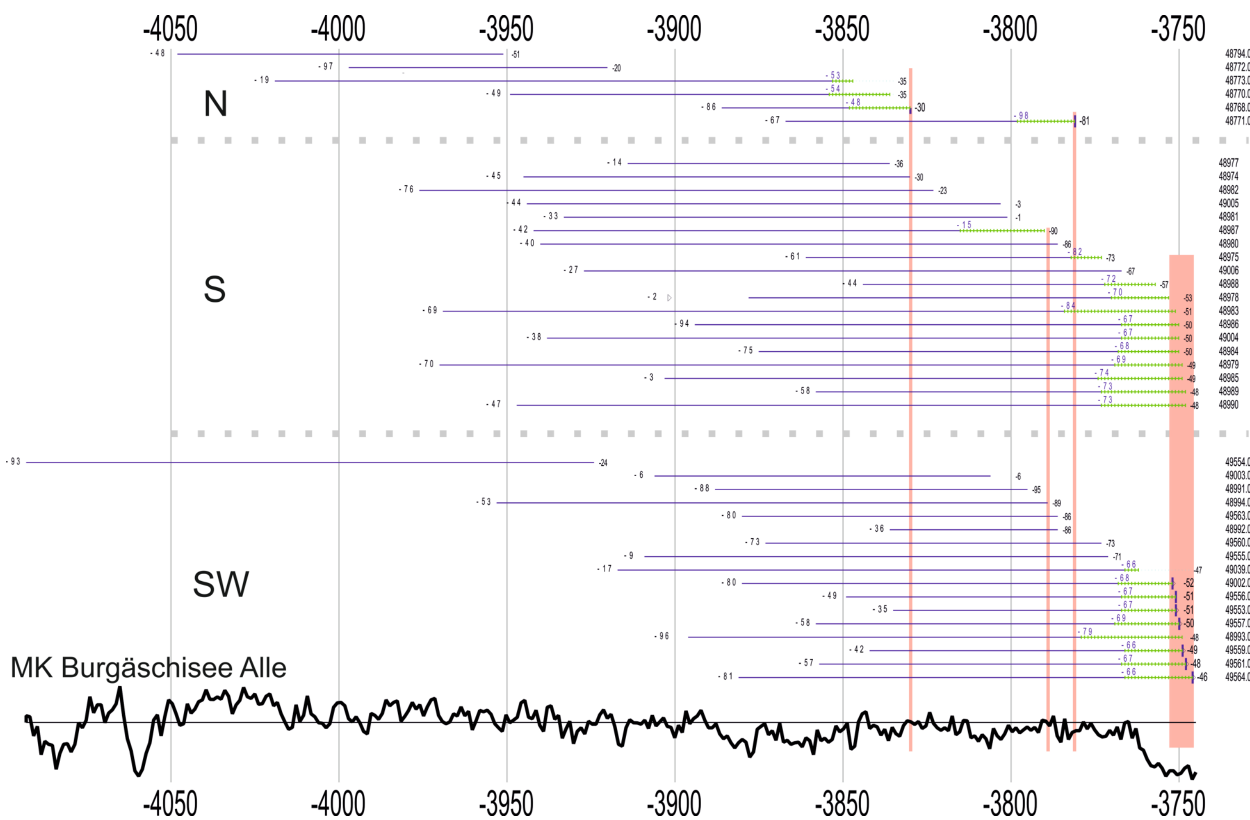

Figure 13: Aeschi SO, Burgäschisee, Nord. Dendrochronologically dated oaks. Green dotted lines: sapwood. Vertical red lines: settlement phases.

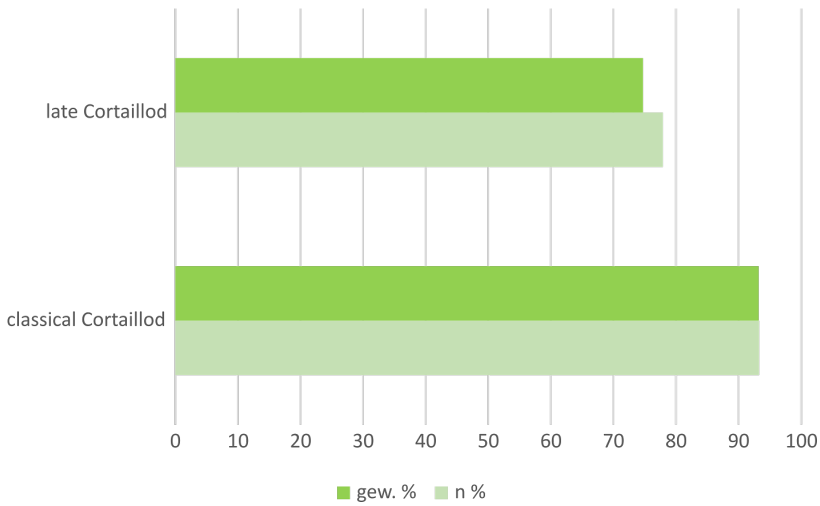

Figure 14: Burgäschisee Nord. Proportions of animals hunted in the classical Cortaillod Culture (wild animals n = 2153, weight = 34.1 kg, total identified bones n = 2308, weight = 36.6 kg) and in the late Cortaillod Culture (wild animals n = 321, weight = 0.6 kg, total identified bones n = 412, weight = 0.8 kg).

A total of 5,994 hand-retrieved animal bones were analysed (archaeozoological analysis: Marguerita Schäfer, Jörg Schibler). Of these, 2,720 could be identified to species level. The animal bones came from two different chronological periods, with the earlier period dating from the 39th and 38th centuries BC whilst the latter period was dated to around 3600 BC. Wild mammal bones dominated in both periods, making up about 90 percent in fragment numbers and bone weight (Figure 14). This means that hunting provided around 90 percent (classical Cortaillod) or around 80 percent (late Cortaillod) of the mammal meat consumed at the sites and animal husbandry played a minor role. Similar results have already been published for the site at Burgäschisee-Süd dated to the 38th century BC (Figure 15). Judging by the ratios of wild animal species, hunting was highly selective. Red deer (*Cervus elaphus*), aurochs (*Bos primigenius*), wild boar (*Sus scrofa*), and roe deer (*Capreolus capreolus*) were most frequently hunted. These four wild mammal species provided more than 80 percent of the consumed mammal meat. Such a preference for the biggest and heaviest wild mammal species clearly shows an intention to obtain as much meat as possible. Similar examples are known especially from Neolithic settlements of the lake Zurich region, where such selective hunting took place during economic resp. food crisis (Schibler 2017; Schibler and Jacomet 2010). Other, less intensively hunted wild mammal species like badger (*Meles meles*) and beaver (*Castor fiber*) act as an environmental marker for a densely-forested environment with small lakes and streams. They also provide proof of the specific use of fur and other by-products (fat and secretions). Approximately 10 percent of the bones identified belonged to domestic animals, with cattle bones being the most numerous. Domestic small ruminants and pigs were clearly of minor importance and only contributed 1 or 1.5 percent of the meat consumed. Only 11 bones could be identified as dog bones. This result opens up the debate about the use of dogs in the Neolithic. Were they, in fact, used for hunting? A comparison between the chronological periods shows a slight increase in the keeping and slaughtering of domestic animals. This was seen mainly in the larger proportion of cattle bones and decreasing numbers of red deer bones in the later Cortaillod Culture features. Was this the first sign of the impact caused by intense red deer hunting?

As well as hand-retrieved animal bones, small bones from sediment samples were also analysed. Fish, bird, small mammal, amphibian, and reptilian remains are usually invisible to the naked eye. As a consequence, they are often absent from hand-retrieved bone material but can be found in processed archaeobiological sediment samples. Samples were taken at Burgäschisee Nord (trench 1, layers 5.1 and 5.3) and Burgäschisee Südwest and analysed for plant and small animal remains (analysis of small animal remains: Simone Häberle). A total of 30.5 litres of sediment were processed using the wash-over method (Hosch and Zibulski 2003). Processing of small animal remains and species identification was carried out using the equipment and modern animal reference collection of the Institute for Integrative Prehistory and Archaeological Science at the University of Basel. While the analysis of the material from Burgäschisee Südwest is still underway, the analysis of the material from Burgäschisee Nord has been completed and has provided some interesting preliminary results. So far, 4750 small animal remains have been collected from sieves with mesh sizes of 4 and 1 mm respectively. A preliminary analysis has shown that fish, songbirds, small mammals, amphibians, reptiles, and molluscs are represented, with fish (65 percent) and amphibians (33 percent) clearly dominating. Cyprinids such as rudd (*Scardinius erythrophthalmus*) and tench (*Tinca tinca*) as well as perch (*Perca fluviatilis*) and pike (*Esox lucius*) are species typical of the fish stocks in small and nutrient-rich lakes like Burgäschisee and still occur today. Barbel (*Barbus barbus*)

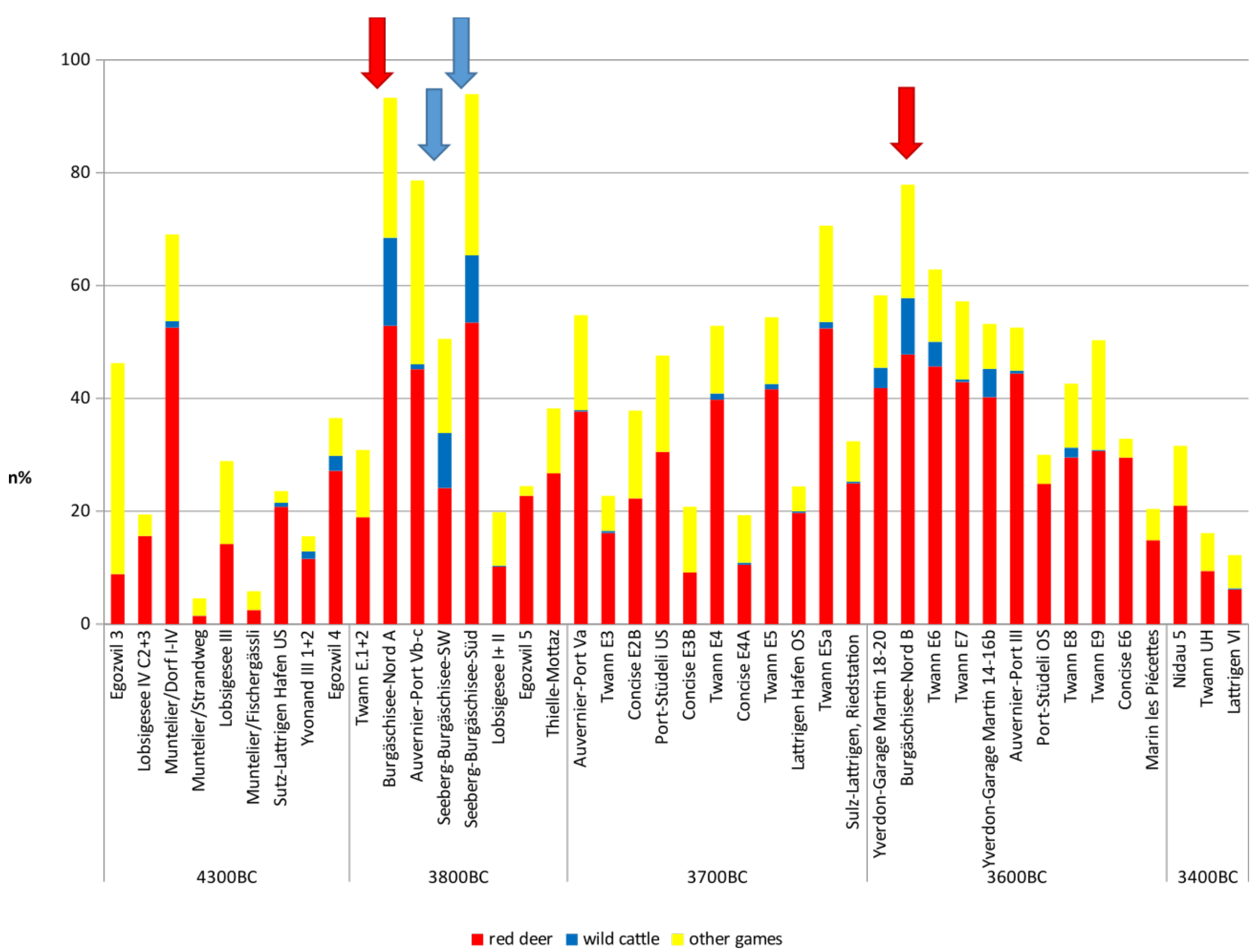

Figure 15: Proportions of hunted animals calculated on the basis of the numbers of identified bone fragments from Neolithic wetland sites in the western part of the Swiss Alpine Foreland (wetland sites see table 1).

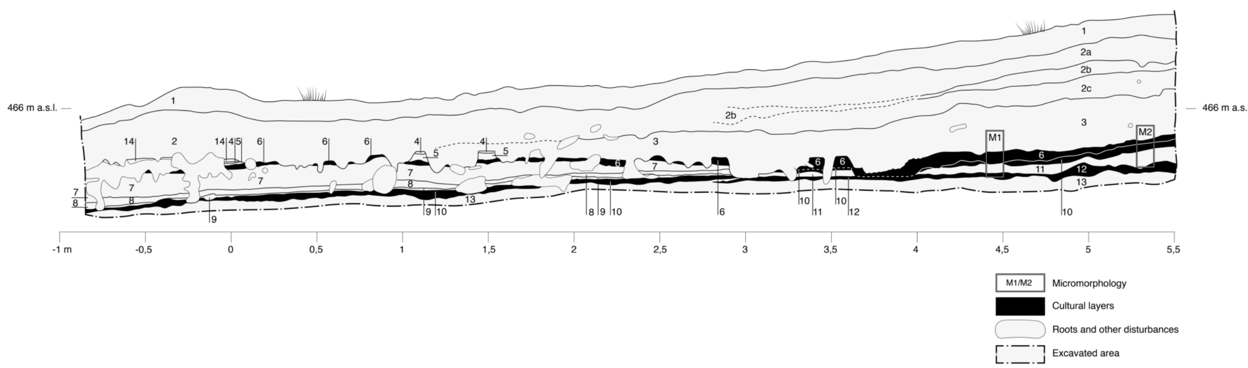

Figure 16: Aeschi SO, Nördlich Strandbad. Trench 4 and location of samples M1 and M2 for geoarchaeological studies.

as well as salmonids like the grayling (*Thymallus thymallus*) indicate that fishing took place not only in the lake itself but also in nearby streams. Some of the amphibian remains were identified as grass/common frog (*Rana temporaria*). This philopatric species spawns in shallow waters that are heated by the sun and are rich in vegetation. Several fish and amphibian remains showed signs of charring and digestion, and can thus be identified as a source of food for the inhabitants of the lakeside dwellings (Hüster Plogmann 2004, 2006; Hüster Plogmann and Häberle 2017).

Charred plant remains have regularly been found at both Burgäschisee Nord and Burgäschisee Südwest (ongoing archaeobotanical analysis: Christoph Brombacher). These mainly include cultivated plants such as barley (*Hordeum vulgare*) and naked wheat (*Triticum durum/T. aestivum/T. turgidum*) and also peas (*Pisum sativum*). Linseed (*Linum usitatissimum*), emmer (*Triticum dicoccon*), and einkorn (*Triticum monococcum*) are also present. The uncharred, subfossil remains, on the other hand, have suffered much due to recent drying out and only a small number of more resistant seeds and fruits, such as hazelnuts, blackberries, raspberries, and elderberries, and a few opium poppy seeds, have survived. The state of preservation appears to have deteriorated since the 1940s and 1950s, at which time it was described as good, and this is illustrated particularly by the low number of taxa and the small quantities of subfossil remains.

Aeschi SO, Nördlich Strandbad

Burgäschisee is delimited to the north and east by moraine ridges from the last phase of glaciation. Excavation trenches located near the actual beach at the foot of the hill at the northern end of the lake were geoarchaeologically studied (analysis: Philippe Rentzel). Profiles were documented in the field and two monolith samples (profile columns in plastic boxes) were taken for micromorphological and geochemical analysis (Figure 16–Figure 17: trench 4, profile P1). In the laboratory, the monoliths were subsampled for geochemistry, then impregnated with synthetic resin and cut into 1 cm thick sections using a diamond saw. Ten petrographic thin sections were prepared for micromorphological analysis and described following the principles set out in Bullock et al. (1985) and Stoops (2003). Geochemical analysis included calcium carbonate content, pH (pH meter in a KCl solution), organic matter content (loss on ignition), humus content (colorimetric method using sodium fluoride as a

Layer	CaCO3	Loss on ignition	Phosphate	Humus	pH
	%	%	(FW)	(FW)	(KCl)
10	0	7.5	2.2	2.6	6.5
11	0	6.5	2.2	1.7	6.1
12	0	8	2.5	1.9	6.2

Figure 17: Aeschi SO, Nördlich Strandbad. Trench 4. Polished section of sample M1 and results of geochemical analysis.

reagent) and phosphate concentration (Braillard et al. 2004). The following paragraphs present the preliminary results based on field studies, micromorphological observations (polished section of sample M1), and geochemical data.

The archaeologically sterile layer 13 at the base of the stratigraphy consisted of a decalcified sandy gravel comprising weathered crystalline components of glacigenic origin. Horizontal bedding and sorting of the gravel pointed to morainic material that had been redeposited in the littoral zone of Burgäschisee. Layer 12 yielded Neolithic artefacts (Cortaillod-style pottery) and was characterised by horizontally oriented fragments of wood and bark as well as compact lumps of loam. The latter, originating from a terrestrial soil horizon (luvisol) was associated with construction work. Degraded organic remains, low organic content, modern roots, and the predominance of resistant elements such as bark at the topmost level pointed to processes of erosion and weathering affecting the cultural layer. A 5 cm thick layer of laminated sand (layer 11) with finer sequences at the top covered the archaeological deposit sealing it off. The decalcified fine to medium sand of the Alpine petrographic spectrum contained some clay, microcharcoal and horizontal bands of degraded organic material, including leaves. Composition and sedimentological traits point to hill-washed glacigenic material, overprinted by limnic processes in a shallow-water depositional environment. As a working hypothesis, erosional phenomena could have been triggered by intensive land use (e.g. agricultural activities on the luvisols) in the immediate surroundings of the prehistoric lakeshore settlements.

The gravel-dominated layer 10 comprises weathered Alpine components of a Bt-horizon, which also derived from a luvisol. This coarse gravel sheet probably accumulated in the wake of intense erosional events affecting the adjacent moraine hills of the hinterland. The ongoing study will focus on questions of potential human impact in connection with the formation of gravel layer 10. Up to 30 cm thick, the sand deposits in layers 6 and 3 again correspond to a sedimentary facies from a shallow water regime, where hill-washed deposits were accumulated. Brownish parts represent phases with a higher input of fine-grained organic detritus, whereas isolated charcoal fragments (up to 1 cm) indicate human presence. Layer 1 corresponds to the actual humus horizon, developed on an artificial dump (layer 2).

In summary, the sedimentary sequence of the Burgäschisee, Nördlich Strandbad outcrop points to a basal archaeological layer (10/12) dating from around 5000 BC (based on four radiocarbon dates and ceramics) which was overprinted by erosional processes and weathering phenomena. In comparison to well-preserved archaeological lakeshore deposits, its significance regarding geoarchaeological interpretations is rather limited (Ismail-Meyer and Rentzel 2017; Ismail-Meyer et al. 2013). However, the overlying hill-washed deposits are an interesting archive and provide important insight into erosional processes dominated by recurrent events (prehistoric land use), which influenced the local landscape evolution.

Seeberg BE, Burgäschisee Süd and Südwest

The neighbouring sites of Burgäschisee Süd and Südwest were examined intensively in the 1940s and 1950s. Excavations were carried out at Burgäschisee Südwest in 1945–1946 and again in 1951–1952, followed by large-scale excavations at Burgäschisee Süd in 1952 and 1957–1958 (Wey 2012). Unfortunately, some of the documentation of the Burgäschisee Südwest site has since been lost. The excavations at Burgäschisee Süd, on the other hand, were carried out using documentation methods similar to what would be regarded as standard today. The Burgäschisee Süd project in particular allowed for modern methods such as radiocarbon dating and dendrochronology to be used. In 1958, the Radiocarbon Dating Laboratory of the Physics Department at the University of Bern published the first radiocarbon dates from the Burgäschisee Süd excavation (Oeschger et al. 1959). In 1963 Huber and Merz found synchronous tree-ring patterns from wooden piles unearthed at Thayngen, Weier, Burgäschisee, Süd and Südwest confirming contemporaneity of the Neolithic sites from around Lake Constance and western Switzerland (Huber and Merz 1963). In 1966 Ferguson, Huber and Suess compared the radiocarbon content of a series of samples of dendrochronologically dated bristlecone pine wood with a floating tree-ring chronology from Burgäschisee and Thayngen, Weier and determined that these sites had existed in the period between 3700 and 3600 BC (Ferguson et al. 1966). The results of the Burgäschisee Süd project were published in a series of eight monographs whose scientific presentation is still very convincing (Bandi et al. 1973; Bleuer et al. 1988; Boessneck et al. 1963a; Brunnacker 1967; Müller-Beck and Flükiger 2005; Müller-Beck and Schweingruber 1965; Müller-Beck and Wey 2008; Wey 2012).

Much like Burgäschisee Ost, Burgäschisee Süd/Südwest also yielded an older phase with Egolzwil pottery dating from 4300–4200 BC. Dendrochronological analysis confirmed the existence of a phase dating from around 3750 BC at Burgäschisee Süd, whilst radiocarbon dates from the 1950s yielded more recent dates in the second half of the 4th millennium BC. The 2016–2017 campaigns at Burgäschisee Süd and Südwest were limited by dense vegetation and by changes in the shoreline since the 1950s excavation. Four trenches (46 m^2 in total) were dug within the area of Burgäschisee Süd that had been excavated in 1957–1958, primarily for the gathering of additional dendrochronological samples. Two trenches at Burgäschisee Südwest each yielded a settlement horizon containing loam layers, which can most probably be interpreted as the remains of floors. A total of 150 samples taken in 2016–2017 from piles in the area excavated in 1945 now offered an opportunity to obtain new dendrochronological dates around 3750 BC (Figure 13).

Palaeoecological investigations: vegetation and fire dynamics between 12,500 and 800 BC

Palaeoecological analyses on sediment cores retrieved in 2009 were carried out as part of the Marie-Heim-Vögtlin SNSF project ‘Societal responses to prehistoric climate changes in Central and Southern Europe: combining palaeoclimatic, palaeoecologic, and archaeologic evidence.’ (applicant: Erika Gobet). Subsequently, new cores were obtained in 2014

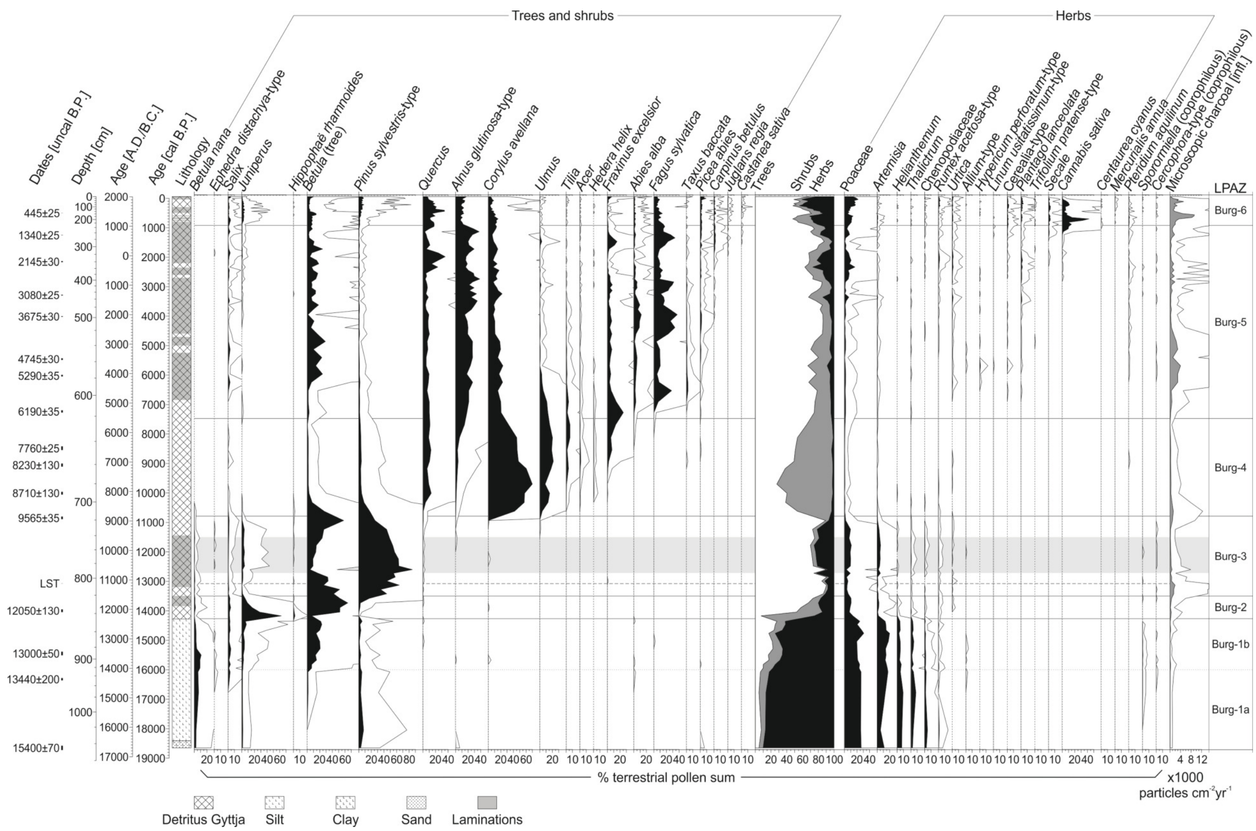

Figure 18: Burgäschisee. Pollen diagram (Rey et al. 2017).

during the SNSF project (applicant: Willy Tinner) entitled 'Exploring eight millennia of climatic, vegetational and agricultural dynamics on the Swiss Plateau using annually layered sedimentary time series' (Figure 18; Rey et al. 2017). After deglaciation, the first steppe tundra communities established during the Late Glacial, at the onset of the Oldest Dryas, c. 17,000 cal BC. As observed in many lowland records, initial afforestation in the Burgäschisee region also began with a mass expansion of *Juniperus* shrubs which invaded the steppic tundra of the Oldest Dryas. This vegetational shift preceded the establishment of *Betula* woodlands at the onset of the Bølling period c. 12,550 cal BC. Mixed *Pinus sylvestris* and *Betula* forests formed during the subsequent Allerød period (11,950–10,950 cal BC). This late glacial vegetation succession is typical of the entire Swiss Plateau (e.g. Wick 2000; Lotter 1999) and other Central European regions (e.g. A. Becker et al. 2006; Kleinmann et al. 2015). Fairly closed forests in combination with stable and warm summer temperatures (Heiri et al. 2015) may have led to an increase in regional fires as represented by a rise in charcoal influx values. During the Younger Dryas cooling (10,950–9550 cal BC), the steppic tundra vegetation (e.g. *Artemisia, Poaceae*), typical of the Oldest Dryas (before 12,550 cal BC), partially expanded and forests opened up; *Betula* declined and *Pinus sylvestris* began to dominate. Forest composition changed at the onset of the Holocene around 9700 cal BC as a result of rapid warming (Heiri et al. 2015), and boreal forests were gradually replaced by temperate forests with deciduous *Tilia, Ulmus, Quercus*, and *Corylus avellana*. These trees and shrubs dominated Central European forests for over 4,000 years during the Early Holocene (e.g. Ammann 1988; Clark et al. 1989; Hadorn 1992; Lotter 1999). Vegetation only changed significantly from c. 6550–6050 cal BC when *Alnus* and *Fraxinus*, together with mesophilous trees such as *Abies alba* and *Fagus sylvatica* established, most likely in response to the more humid summer conditions in the mid Holocene (Tinner and Lotter 2006).

The onset of noticeable agricultural activities in the pollen record from the Burgäschisee region has been dated to c. 4550 cal BC (first occurrence of Cerealia-type and *Plantago lanceolata* pollen, see Figure 18). This finding coincides with individual archaeological Neolithic finds dating from the period after 4300 cal BC and with the existence of local settlements after c. 3850 cal BC. The expansion of arable and pastoral farming as indicated by pollen from crops and weeds (e.g. Cerealia-type, *Plantago lanceolata*, *Linum usitatissimum*-type) and the re-expansion of disturbance-adapted shrubs (*Corylus avellana*) and pioneer trees (*Betula*) is typical for the Central European lowlands. These land use disturbances generated marked vegetation shifts and successional cycles (e.g. Clark et al. 1989; Kleinmann et al. 2015; Rösch and Lechterbeck 2016; Rey et al. 2019; Tinner et al. 2005a). Fire activity increased, suggesting that fire was used intensively to create open land, most likely by means of slash-and-burn activities. Forest fires set for agricultural purposes significantly reduced fire-sensitive species (e.g. *Tilia, Ulmus, Fraxinus, Abies alba*, see also Tinner et al. (2003)). Subsequently, land use intensified during the Middle Bronze Age (around 1550 cal BC) and many disturbance-sensitive trees such as *Tilia* and *Abies alba* disappeared locally (Rey et al. 2017). The comparison of the paleoecological record of Burgäschisee with the vegetational pattern observed at other sites suggests that land use and deforestation phases were synchronous and thus likely linked to climate change (Rey et al. 2019). Earlier explanations developed for the Metal, Roman, and Early Middle Ages assume that warm-dry climatic conditions triggered increases of cereal yields and thus higher carrying capacities that resulted in further deforestation and slash and burning pulses (Tinner 2012; Tinner et al. 2005b, 2003) and subsequent land use intensification. When climate became cooler and moister, cereal-based carrying capacities declined, leading to land abandonment in marginal areas and subsequent spontaneous afforestation successions. Our new palaeoecological investigations suggest that this explanatory model can be adopted for the Neolithic period. The synchronisms in land use pulses extend to southern Europe, across different cultures north and south of the Alps, making societal triggers very unlikely (Rey et al. 2019).

Modelling population density and land use in Western and Central Switzerland

The increased interest in the subject of complexity in archaeology have created and pushed a research agenda for model-based archaeology focused on investigating and gaining a better understanding of coupled human and natural systems, complex adaptive systems, human/societal resilience to environmental, and social deterioration, the emergence of inequality, and many more topics (e.g. Barton 2014; Kohler and van der Leeuw 2007; Lake 2014; McGlade 2014; Wurzer et al. 2015). Therefore, within the scope of the project 'Beyond lake villages: Studying Neolithic environmental changes and human impact at small lakes in Switzerland, Germany, and Austria', special emphasis was put on the creation of well-informed simulation models for small lake communities and larger geographical regions to estimate land use and population densities during the Neolithic. The models require elaborate hypotheses with regard to past human-environmental relationships originating from the archaeological and paleoecological evidence and theoretical models of (past) human behaviour in space and time.

The investigated communities' size, subsistence strategy, and the occupation time of a site must be known to estimate their land use. These set of variables are enigmatically represented by the archaeological record. The land surface area used by a community for its subsistence is relative to its size. However, depending on the characteristics of the mode of production, e.g. the composition of livestock and cultivated plants, labour organisation, technological standards, exploitable resource conditions, etc., land use patterns will differ from community to community and change over time (Boserup 1996; Gregg 1988; Hughes et al. 2018). A dynamic, agent-based land use simulation of wetland settlements (WELASSIMO) in southern Germany and on Lake Zurich was recently presented by Baum (Baum 2014, 2016). As an archaeologically well-informed land use simulator WELASSIMO includes specific components of subsistence economy such as crop cultivation and cattle husbandry systems for the excavated sites under investigation. Simulations of different crop cultivation scenarios led to the conclusion that permanent crop cultivation was the more likely system to have been employed than shifting cultivation (Baum et al. 2016; Jacomet et al. 2016).

In order to go on the task of simulating the land use on a mesoregional scale the archaeological database is insufficient for such a task as in many cases the documented sites do represent only a fraction of former numbers and additionally often they cannot provide us with an estimate of its number of inhabitants or its total duration. However, the wealth of information gained from Neolithic wetland sites over several decades of archaeological research and paleoecological studies enables us to formulate reasonable hypotheses about the subsistence strategies of past communities, including foraging, farming and animal husbandry (e.g. Doppler et al. 2017; Jacomet 2008; Schibler 2008), their social organisation and settlement dynamics (e.g. Ebersbach 2010; Hafner and Suter 2003; Hofmann et al. 2016; Röder et al. 2013), their impact on vegetation through land use (e.g. Rey et al. 2017; Tinner et al. 2005b; see former section) and their ways of coping with environmental change or instability (e.g. Arbogast et al. 2006; Magny 2004). The Swiss part of the «Beyond Lake Villages» project tries to use computational simulation models that already exist and combine them to a functional simulation model suited to test the empirical models and data-driven hypotheses about the western and central Swiss Neolithic generated by archaeological research and paleoecological land use reconstructions.

To achieve this goal, a scaled down, regional version of the 'Global Land Use and technological Evolution Simulator' (GLUES) is being employed. The mathematical simulation model GLUES describes coupled human-environmental systems and has previously been used to simulate the Neolithic transition (Lemmen et al. 2011; Lemmen and Wirtz 2014; Wirtz and Lemmen 2003) and to estimate pre- and protohistoric carbon releases caused by deforestation on a global scale (Lemmen 2009). GLUES is a spatially explicit and dynamic numerical model that simulates the population density and three dimensionless socio-cultural traits of societies (agents) inhabiting a relatively large biogeographical region. The adaptive dynamics of GLUES are defined by the four variables of population density, technological efficiency, subsistence economy, and economic diversity, which coevolve in the context of the changing availability of natural resources as defined by vegetation productivity and climatic constraints. Technological efficiency includes not only the available physical means such as the workforce and tools but also the organisational structures that influence the efficiency of food production. Subsistence economy or farmers' share is the proportion of effort put into an agro-pastoral farming economy, where 0 stands for a lifestyle based solely on foraging. This variable is used as a threshold for defining a society as Neolithic. Economic diversity describes the number or diversity of economic strategies a society practises in the sector of food production. The population dynamics (growth and decline) of an agent are directly coupled with the development of three socio-cultural traits and the environment's resource utility. In turn the traits follow the direction of increase or decrease of its associated agent (Wirtz and Lemmen 2003).

An agent in GLUES is defined as the population of a relatively large biogeographical region. For the «Beyond Lake Villages» project simulation model LUTES (Land Use and Technological Evolution Simulator), on the other hand, the agent represents a social entity that is organised in several groups forming a settlement. The rescaling of the spatial reference area including the natural resources each agent utilises to satisfy its needs is already applied. Different environmental variables (e.g. slope, soil, temperature, precipitation) have an impact on the suitability of a given location for various socio-economic purposes. The number of neighbours in the agent's social network is defined by the variable of spatial distance, which also describes the strength of interaction between them. At the current stage of our work we are further integrating and enhancing existing agents behaviours including their choice of settlement location, interaction, mobility, and their economic strategies. We are also refining the rough foraging-farming dichotomy of GLUES. The possibility to feed GLUES with data from other simulation models and vice versa (Lemmen 2009) has prompted the linkage to WELASSIMO (Baum 2016; Baum et al. 2016) to estimate land use in geographic space and feedback into sub-models of the «Beyond Lake Villages» project simulation model.

Discussion/Conclusion

As an intermediate result, we present here phases of Neolithic human impact from palaeoecology combined with archaeological data (typology, radiocarbon, dendrochronology) from different sites at Burgäschisee (Table 1). First human impact and the beginning of agriculture in Central Switzerland dates back to around 5000 BC. Despite some evidence for early farming attempts reaching back to the Late Mesolithic (Stöckli 2016; Tinner et al. 2007; Welten 1982), we assume that the period 4800–4500 BC is crucial for the development of sedentary farming societies in northern-alpine forelands: more and more indicators convince us to set the onset of fully established agricultural economies in this time slot of the early 5th millennium BC. Indicators are settlement activities in the Alpine

Table 1: Burgäschisee. Phases of human impact and/or settlement activity between 4600 and 2600 BC. [1] dendrochronology, precise waney edge data; [2] dendrochronology, estimated sapwood data.

Chrono-logy **Phases BC**	**Palaeo-ecology** **Phases of human impact**	**Archaeology chronological data (typology, radiocarbon, dendrochronology) Sites at Burgäschisee:**					
		Ost	**Hintere Burg**	**Nördlich Strandbad**	**Nord**	**Südwest**	**Süd**
2800 – 2600	•	ceramics Corded Ware type singular (old) finds	^{14}C		2840 – 2810 cal BC ^{14}C wiggle matching		^{14}C
3200 – 3000	•		^{14}C				^{14}C
3800 – 3600	•	3900 – 3780 cal BC wig-gle match-ing		^{14}C Layer 3	3780 BC[1] 3835/3830 BC[2]	3752 – 3746 BC[2]	after 3750 BC[2] 3790 BC[2]
4300 – 4000	•	ceramics Egolzwil type singular (old) finds	^{14}C	^{14}C Layer 6			
5000 – 4700	•			^{14}C Layer 10–12			

Rhine Valley (Zizers), first use of alpine pastures in the Bernese Alps (Iffigsee/Schnidejoch) and an earliest phase of Neolithic stone cists graves in the Alpine Rhone Valley (Hafner 2015). A next phase of settlements at Burgäschisee starts in the late 5th millennium BC. This phase is in agreement with settlements in other parts of Central Switzerland (Egolzwil). The following centuries of the early 4th millennium BC form the best represented phase of Neolithic settlements and human impact. Comparable phases are well documented in Switzerland and Southern Germany (Three-Lakes Region, Lake Zurich, Lake Constance). The late 4th millennium which is usually one of the most densely represented settlement phases in Switzerland is clearly underrepresented at Burgäschisee and remains below expectations. The Neolithic sequence ends in the moment with a settlement phase in the early 3rd millennium BC. A time slot just before 2800 BC is clearly proven by a combination of dendrochronology and radiocarbon dating. This indication is more than five decennia before the assumed arrival of Corded Ware ceramics in Central Switzerland. This kind of typical ceramics has been found as a few singular sherds in former large-scale excavations and indicate settlement activities dating around 2700–2600 BC as well.

In Switzerland, in the years 2015–2017 research within the project 'Beyond lake villages: Studying Neolithic environmental changes and human impact at small lakes in Switzerland, Germany and Austria' focused on three spatial levels of investigation. First, archaeological investigations concentrated on different types of sites around Burgäschisee with a strong potential to prove prehistoric settlement activities of sedentary societies with agricultural economies. The aims were: (1) to investigate settlement areas on the lake shore and in a clear wetland context and, (2) to find settlements areas on mineral soils in the direct hinterland. Excavations in wetland context consisted of re-opening of formerly excavated trenches with the goal to get wood material for new dendrochronological dating. In order to get insight into the stratigraphy of undisturbed wetland settlement areas selected new trenches were opened as well. On mineral soils and off the lake shore selected trenches were investigated mainly in suspected slope areas. Here tiny prehistoric settlement traces were assumed under thick layers of accumulation. The second spatial level of investigation consists of palaeoecological research on vegetation, land use, and fire dynamics of the Holocene. Burgäschisee lake sediments are an exceptional archive in Central Switzerland covering more than 18,700 years of vegetation history including most of the archaeological settlement phases during the last c. 6,800 years. Laminated sediments of Burgäschisee store traces of human activities near the lake and in a distance of 5–10 km around the lake and deliver major information on agricultural activities like cereal production and livestock farming. With the onset of fully agriculture-based economies ca. 7000 years ago, vegetation changes became primarily controlled by human activities, including fire disturbance under relative stable climate conditions. Laminated sediments of Burgäschisee indicate cycles of deforestation and reforestation which reflects presence or decrease of human populations within the immediate vicinity of the lake. Increase or decrease of human populations could be triggered by wetter climatic conditions which made settlement areas near the lake shores uninhabitable due to rising water tables in already marshy areas surrounding Burgäschisee. More generally, wetter conditions may have substantially affected Neolithic crop production and thus carrying capacity as well as population density, as assumed for the subsequent prehistoric times for wide areas in and around the Alps (Gobet et al. 2003; Rey et al. 2017; Tinner et al. 2003). The focus of our third spatial level of investigation is extending beyond the Burgäschisee area and covers Western and Central Switzerland. Modelling of land use, anthropogenic land cover change and population densities during the Neolithic in an extended area contributes substantially to our understanding of past human-environment relationships. Bringing together the new data from all three levels of investigation will allow to describe in a substantial way evolutionary processes of landscapes and human populations (Table 1).

Acknowledgements

We would like to thank Pierre Harb and Adriano Boschetti, heads of the Archaeological Services of Cantons Solothurn and Bern for supporting the Burgäschisee research 2012–2017 in many ways. Albert Hafner thanks Othmar Wey for directing the archaeological field work at Burgäschisee and the students from the Universities of Bern and Basel for their efforts. Many thanks also to Corina Gottardi, student assistant, for transforming the analogue Burgäschisee site plans from previous excavations of the 1940/1950ies into highly useful GIS-based plans (with the support of Corinne Staeheli, student assistant), to Susanna Kaufmann for the graphic realisation of illustrations, to Christine Rungger for the drawing of ceramics in Fig. 9 and to Sandy Haemmerle, Galway, Ireland for translation and proofreading of the manuscript. We are also grateful to the Däster-Schild Foundation, Grenchen, Switzerland for covering the costs incurred by having drawings made of the pottery. The research was mainly funded as part of two Swiss National Science Foundation projects: 'Beyond lake settlements: Studying Neolithic environmental changes and human impact at small lakes in Switzerland, Germany and Austria.' SNSF-Interdisciplinary project no. CR20I1L_152862 (main applicant: Albert Hafner) and 'Exploring eight millennia of climatic, vegetational, and agricultural dynamics on the Swiss Plateau using annually layered sedimentary time series'. SNSF-Project funding in Mathematics, Natural sciences, and Engineering (division II) no. 200021_149203 (main applicant: Willy Tinner).

Tables

Table 2: Table to Figure 15

Sites	Bibliography	Years BC
Egozwil 3	Stampfli 1992	4282–4275/4260
Lobsigesee IV C2+3	Ginella and Schibler n.d.	3900–3850
Muntelier-Dorf I–IV	Lopez 2003	3867–3826
Muntelier-Strandweg	Reynaud 2005	3851–3837
Muntelier-Fischergässli	Morel 2000	3842–3819
Sutz-Lattrigen Hafen US	Kerdy n.d.	3834–3820
Yvonand III 1+2	Chaix 1976b	3800
Egozwil 4	Stampfli 1992	3860
Twann E.1+2	Stampfli 1980	3838–3768
Äschi-Burgäschisee-Nord A	Schäfer/Schibler in prep.	3840–3780
Auvernier-Port Vb–c	Chaix 1985	3791–3785
Seeberg-Burgäschisee-SW	Josien 1956, Stampfli 1964	3760–3748
Seeberg-Burgäschisee-Süd	Boessneck et al. 1963b	3760–3748
Lobsigesee I+ II	Ginella and Schibler n.d.	3750–3700
Egozwil 5	Stampfli 1976	3740
Thielle-Mottaz	Chaix 1979	3719–3699
Auvernier-Port Va	Chaix 1985	3728–3679
Twann E3	C. Becker and Johansson 1981	3702–3687
Concise E2B	Chiquet 2012	3692–3676
Port-Stüdeli US	Stampfli et al. 2003	3686–3638
Concise E3B	Chiquet 2012	3666–3656
Twann E4	C. Becker and Johansson 1981	3663–3658
Concise E4A	Chiquet 2012	3645–3636
Twann E5	C. Becker and Johansson 1981	3643–3631
Lattrigen Hafen OS	Kerdy n.d.	3641–3631
Twann E5a	C. Becker and Johansson 1981	3622–3607
Lattringen VII H innen	Kerdy n.d.	3613–3566
Yverdon-Garage Martin 18-20	Chaix 1976a	3600

Table 2: Table to Figure 15 (*continued*)

Sites	Bibliography	Years BC
Äschi-Burgäschisee-Nord B	Schäfer/Schibler inprep.	3600
Twann E6	C. Becker and Johansson 1981	3596–3573
Twann E7	C. Becker and Johansson 1981	3596–3573
Yverdon-Garage Martin 14–16b	Chaix 1976b	3588–3581
Auvernier-Port III	Chaix 1985	3627–3621/3560–3550
Port-Stüdeli OS	Stampfli et al. 2003	3560
Twann E8	C. Becker and Johansson 1981	3563–3532
Twann E9	C. Becker and Johansson 1981	3563–353
Concise E6	Chiquet 2012	3533–3516
Marin les Piécettes	Chiquet 2006	3504–3483
Nidau 5	Glass and Schibler 2000	3406–3398
Twann UH	Stampfli 1980	3405–3391
Sulz-Lattringen, Riedstation	Glass and Schibler 2000	3393–3388

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New perspectives on archaeological landscapes in the south-western German alpine foreland — first results of the BeLaVi Westallgäu project

11

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Introduction

Annually laminated lake sediments contain an amazing wealth of evidence on activities of prehistoric communities. If it is possible to link their palaeoenvironmental, palaeoeconomic, and palaeoclimatic information precisely to waterlogged archaeological evidence, prehistoric human presence can be detected in a resolution and on a spatial scale far beyond conventional lake dwelling research. The successful methodological combination of on-site and off-site approaches in the same microregion was one of the core outcomes of a research project carried out between 2008 and 2010, which focused on Degersee, a small lake in southwest Germany, in the hinterland of Lake Constance (Mainberger et al. 2015b)*. In the same years it became evident that small lakes in the Swiss Plateau provided comparable datasets of high-resolution data covering several thousand years of postglacial human-environmental interaction (Tinner et al. 2006). Based upon those studies, the trinational project 'Beyond Lake Settlements: Studying Neolithic environmental changes and human impact at small lakes in Switzerland, Germany and Austria' (BeLaVi) aims to develop a bigger and at the same time more detailed picture of the northern pre-alpine prehistoric landscapes and their transformation by humans†.

Off-site observations from palynology like changes in vegetation cover and composition indicate both natural phenomena such as climate changes and anthropogenic influences such as woodland clearing and subsequent forest successions (Kleinmann et al. 2015). Distinguishing natural from human impact and quantifying and qualifying the importance and intensity of human activity on observed landscape changes has been one of the central methodological challenges of wetland archaeology and palaeoenvironmental research for a number of decades (cf. Azuara et al. 2015; Martinelli et al. 2017; Schwörer et al. 2014; Ye et al. 2013). Within the BeLaVi project, the correlation of anthropogenic indicators from off-site data with archaeological evidence and on-site environmental data in the immediate vicinity, combined with high resolution absolute dating will allow a better understanding of how to distinguish between natural and human impacts in different regions. We expect that agricultural systems and techniques like fire management of woodland

* This project has been generously funded by the German Science Foundation (DFG). We would also like to thank the DFG for the funding of the Westallgäu project within the framework of BeLaVi.
† Project partners are the Universities of Bern (CH), Vienna (A) and the State Office for Cultural Heritage Baden-Württemberg (D). Research activity is funded by the Swiss National Science Foundation (SNSF), the Austrian Science Fund (FWF) and German Science Foundation (DFG). More than 50 scientist were appointed to six working-groups, one archaeological and one paleoenvironmental unit per country. The three-year project schedule started in 2015.

Mainberger, M., T. Baum, R. Ebersbach, P. Gleich, R. Hesse, A. Kleinmann, U. Maier, J. Merkt, S. Million, O. Nelle, E. Stephan, H. Schlichtherle, R. Vogt, L. Wick (2020). 'New perspectives on archaeological landscapes in the south-western German alpine foreland — first results of the BeLaVi Westallgäu project'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 205–232. DOI: 10.11588/propylaeum.714

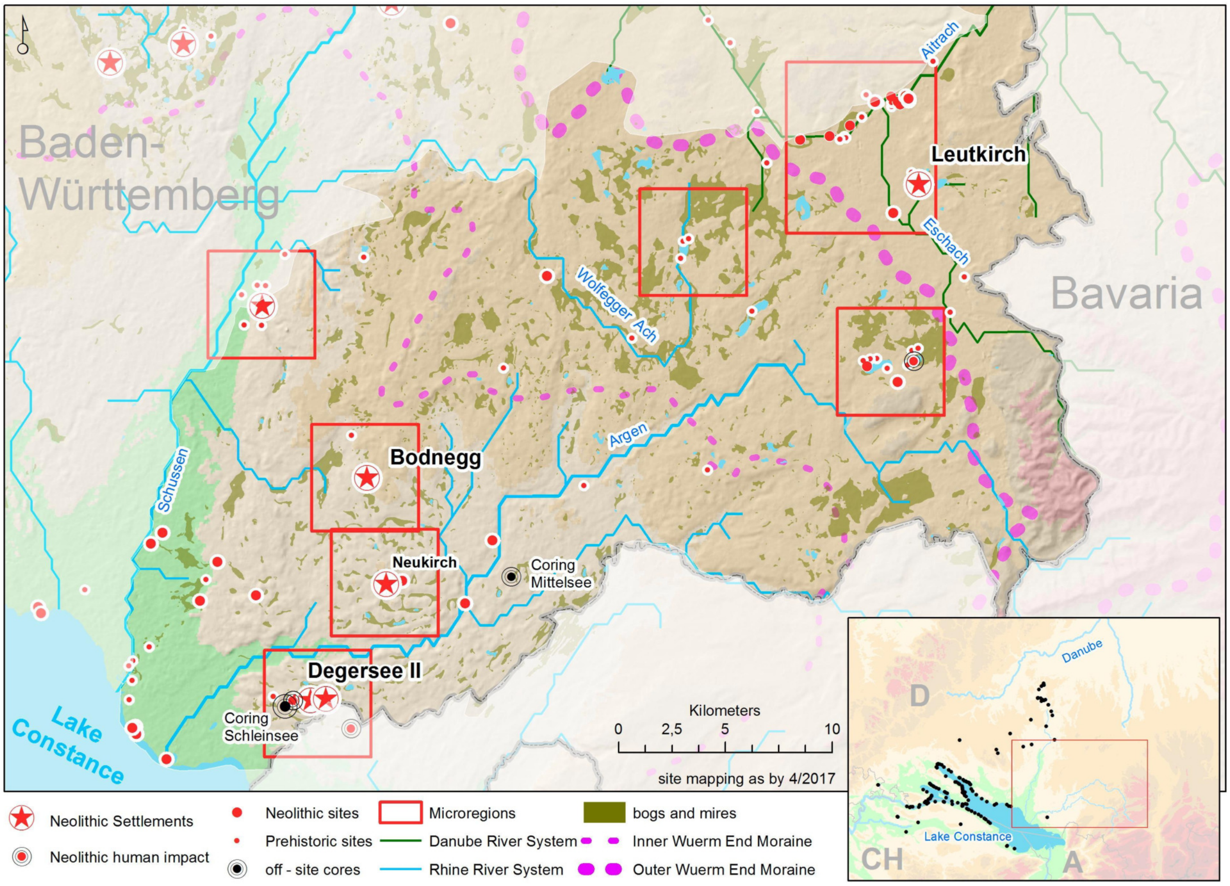

Figure 1: Study area with sites and microregions in SW Germany north of Lake Constance. The overview map shows the state of research as of 2011.

as well as questions of demography and population density will be better understood on this larger geographic scale.

Three areas are in the focus: (1) the Swiss Plateau with Burgäschisee, a small lake, at its center, (2) the Westallgäu between Lake Constance and the western tributaries of the river Iller (Figure 1), and (3) the Salzkammergut in Austria with the lakes Attersee and Mondsee. We expect that the comparison of these three study areas, each with its respective specific natural environments and cultural traditions, will result in a variety of possible scenarios of how Neolithic communities adapted to changing environmental conditions. Due to its significant oscillations of climate and distinct changes in material cultures (cf. Daim et al. 2011; Schlichtherle 2011), the 4th millennium BC is of special interest.

The following paper‡ presents first results and discussions from the Westallgäu part of the project.

‡ This paper is a result of two presentations held at the workshop TH6-11 "Settling waterscapes in Europe: the archaeology of Neolithic and Bronze Age pile-dwellings" at Vilnius during the 22nd EAA meeting. We would like to thank J. McIntosh, Freiburg i. Br., for editing works on the English text.

The study area: physical conditions, taphonomic issues, and outer boundaries

The physical landscape of the Westallgäu is dominated by three main elements: the last glacial (Würm) outer and inner terminal moraines and the river Argen (Figure 1). The outer terminal moraine indicates the extent of the Rhine glacier at the time of the last glacial maximum. It forms a large crescent that encloses a hilly landscape dominated by glacial, periglacial, and fluvial landforms such as drumlins, moraines, river valleys, and terraces. The topography ascends from the basin of Lake Constance and the Schussen valley northward to the outer terminal moraine and eastward and southward to the Alps. The inner terminal moraine marks a stagnation in the retreat of the Alpine ice shield. The river Argen, with its Lower Argen (*Untere Argen*) arm, cuts through this moraine belt and forms the main hydrological axis of the Westallgäu, subdividing the study area into northern and southern sections. While the Argen flows into Lake Constance and is part of the Rhine catchment area, the small rivers beyond the outer terminal moraine flow northward and are tributaries of the Iller and Danube catchments. The European continental water divide that separates the North Sea drainage system from the Black Sea drainage system follows the terminal moraines. Due to the poorly developed postglacial hydrological system (headwater erosion has not yet reached large portions of the region), the formerly glaciated area in general and the terminal moraines in particular are marked by a multitude of wetlands and waterscapes. Peat growth and siltation filled most topographic depressions during the Holocene. Only recently, in the 19th and 20th centuries, rural engineering measures have changed many of these wetlands to arable land.

The Westallgäu is part of the central European oceanic temperate climate zone (Cfb; after Köppen 1936) with moderately warm summers, mild winters, and prevailing westerly winds. Most rain falls during the summer months. Climatic differences within the study area are mainly due to the ascent of the relief towards the east. Mountains like the *Pfänder Massiv* and the *Adelegg* in the east of the study area are submontane sections of the Allgäu Alps. As a result, precipitation rises from about 1000 mm in the west (Ravensburg) to 1600 mm in the east (Isny). Mean annual temperatures decrease accordingly; the difference between Ravensburg (8.8°C) and Isny is 1.6°C. A climatic peculiarity of the landscape is the *Föhn*, a warm, downslope wind from the Alps.

In a strong contrast to the well-researched landscapes of Upper Swabia and western Lake Constance, which are adjacent to the west of the study area, the Westallgäu was archaeologically *terra incognita* until recently (Figure 1; Hagmann et al. 2011, p. 6). The blank space on the distribution maps was explained by palaeoenvironmental and climatic factors (Krahe 1958, p. 37; Schlichtherle 1985, p. 18).

However, in the light of the discoveries of the Degersee project, taphonomy seems to be the main reason behind the empty map up to now. While Upper Swabia is traditionally characterised by agriculture, the Allgäu nowadays has its economic bprofundal zoneackground in cattle breeding and dairy farming.

This is a result of a turbulent shift in economy in the 19th century, when Allgäu agriculturalists changed their farming strategies to a dairy produce economy. As a consequence, formerly ploughed farmland was changed into meadows and pastures. This fact had an important influence on the chances of survival or even discovery of an archaeological object or site. In comparison to the open farmland in Upper Swabia and Linzgau the green hills and forested hilltops of the Allgäu were — and still are — much less accessible to archaeologists and local volunteers, who played a major role in the history of archaeological research going back to the 1930s (Reinerth 1956). Furthermore, building and infrastructure activities are less intense than the growing agglomerations around Lake Constance or more industrialised parts of Upper Swabia.

The outer boundaries of the investigation area Westallgäu are defined by a combination of natural and administrative borders. Lake Constance and the river Schussen mark two distinct natural borders to the south and west. The eastern border is defined by the administrative boundary between the federal states of Baden-Württemberg and Bavaria. The northern border is limited by geographical elements as defined by Dongus (1991). It is self-evident that a perimeter defined by such a mixture of different parameters reflects an area of interest rather than any border that was valid in prehistory.

Approaches, concepts, methods

'Beyond Lake Villages' conceptually implies expanding the area of interest to the hinterland of the intensively researched large pre-alpine lakes and therefore to the landscape rather than to individual sites. Consequently, off-site investigations, against the background of the results of the Degersee project (Kleinmann et al. 2015), constitute a central strategic pillar within the project. The methodological approach used is based on several decades of research experience (Clark et al. 1989) and has been refined in the Degersee project (Kleinmann et al. 2015).

The strategy developed during the Degersee project was to combine off-site and on-site studies in the same lake. Off-site sediments from long cores in the profundal zone of the lakes provide highly resolved sections without hiatuses. They reflect microregional influences from the catchment and are often annually laminated. Densely sampled radiocarbon AMS data provide a reliable chronostratigraphical framework which allows the chronological interconnection with archaeological and scientific on-site data revealing local signals. Off-site studies, in particular, aim at disentangeling human impact from the forces of nature. A novel strategy to achieve this aim is comparing relevant data from a lake close to prehistoric sites such as Degersee with lakes some distance away and potentially less influenced by human impact such as Schleinsee and Mittelsee (reference lakes) (Figure 1).

Off-site field methods and analysis of the respective samples applied state-of-the-art techniques. Sediments of undisturbed long cores (Merkt and Streif 1970) were densely and continuously sampled and prepared for pollen analysis (Moore et al. 1991; Stockmarr 1971), loss-on-ignition (Kleinmann et al. 2015) and microfabric analysis (thin-sections, Merkt 1971). Terrestrial macroremains were cleansed with 200 or 300 μm mesh sieves for AMS dating. XRF-Scans were executed in 200 μm steps on fresh surfaces of cores for geochemical composition.

The counterpart to off-site-investigations are archaeological and scientific on-site studies. Based on a long tradition of settlement archaeological concepts (Jankuhn 1977), which have successfully been adopted to the Swiss and the German northern Alpine foreland from the 1980s on (Schlichtherle 1991, 2009), they include observations on spatial scales much larger than single settlements and their vicinity. However, the specific character of the investigation area demands an approach slightly different from comparable investigations in the loess regions, where landscape archaeological concepts were initially developed (for details on the history of research see Zimmermann, 2014). The short hydrological history of the area has shaped an immature drainage system with waterscapes rather than landscapes. In the vicinity of Degersee, for instance, dry, arable land was restricted to drumlin hills that emerged like islands from an entanglement of reeds, mires, and open water (Mainberger 2009, fig. 3; Mainberger et al. 2015a, p. 523). It has been suggested to conceptualise landscapes so deeply influenced by the presence of aquatic elements and their use by prehistoric communities as 'limnic cultural landscapes' (*limnische Kulturlandschaften*) (Bleile 2010). The concept was originally developed in the field of nautical archaeology by C. Westerdahl. Basically, Westerdahl's concept was to observe archaeological phenomena linked to water from two perspectives – from the land (agricultural) point of view, but also from the perspective 'on board a vessel closing in with the shore' (Crumlin-Pedersen 1978; Westerdahl 2011). Elements of the 'maritime' or 'limnic' cultural landscapes are not only all kinds of sources directly related to water — like settlements, fisheries installations, weirs, watermills, waterfront constructions — but also hilltop forts or natural landmarks (Westerdahl 1998, 40 fig. 3). BeLaVi Westallgäu adopts this complementary approach, leading up to a work discussing the potential role of Upper Swabian watercourses and lakes in the regional traffic systems (Mainberger 2017).

The results presented in this paper relate to three spatial scales (Figure 1): the first level encompasses settlement sites and their direct vicinity (*Siedlungsumfeld)* (Maier 2015; Maier and Vogt 2000; Vogt 2015). The second level describes microregions (*Kleinlandschaften*) that may include several neighbouring sites; the map marks these units as rectangles of up to 7 by 8 km side length. The third, regional level (study area; *Untersuchungsgebiet)* expands from Lake Constance in the southwest to the tributaries of the river Iller in the northeast and is today known as Eastern Upper Swabia or Westallgäu (Benz 2013, 4 for the history and on-going discourse to the term).

The technical principles and standards of southwest German wetland and underwater archaeology have been described often and from different points of view (Dieckmann et al. 2006, pp. 19–45; Mainberger and Hohl 2013; Mainberger 2015, pp. 17–18). The methodology developed by a circle of scientists and technicians at the Wetland Department of the State Office for Cultural Heritage Baden-Württemberg has continuously been adapted to the challenges of new scientific questions, tasks, and technical possibilities. BeLaVi Westallgäu profited much from this expertise. The starting point of archaeological fieldwork was in many cases information provided by locals — we owe most new discoveries and reports relating to unpublished observations to these enthusiasts, with their thorough knowledge of the landscape, oral and written traditions[§]. Remote sensing technologies (satellite imagery analysis, aerial photography), as well as the systematic use of LIDAR data and historical maps proved to be important tools in preparing fieldwork and identifying areas of interest on a microregional level. Archaeological field methods included one-day site visits, several single day systematic surveys, and excavations lasting from a few days to several weeks. Excavation trenches were generally restricted to very small 'keyholes' due to the multitude of sites and tasks and this allowed for stratigraphic observations and sampling for scientific analyses. Archaeological investigations were carried out on mineral soils, wetlands, and in mires as well as in open water.

Geophysical techniques included ground-penetrating radar (GPR) and single beam echo sounder (SBES) technologies. 2500 transects with an interval of 5 m were investigated by GPR. 44 sediment cores were taken to visually identify the structures displayed on the radar.

Dendrochronological, archaeobotanical, palynological, archaeo-osteological, and pedological investigations have long since become standard tools in the scientific assessment of prehistoric settlement sites. The methods deployed and techniques used in Baden-Württemberg have been described on different occasions (see for methodological details Billamboz 2014; Maier 2001, 2016; Vogt 2001, 2014). Generally, samples for botanical, palynological, and anthracological analyses originate from trench profiles; according to specific questions, a number of samples were also taken in excavated areas and from drill cores. High-resolution on-site analyses of pollen, microcharcoal, and non-pollen palynomorphs (NPP) were performed in close cooperation with the archaeobotanical and pedological work. The profile columns recovered for archaeobotanical studies were continuously subsampled for pollen. Additionally, on-site sediment corings were investigated in order to discover traces of local human activities and to estimate the extension of cultural layers as well as their state of preservation. The preparation of the pollen samples with a volume of 1 cm^3 followed standard methods using HF 40 percent and acetolysis (Moore et al. 1991). *Lycopodium* tablets were added for the estimation of pollen and charcoal concentrations (Stockmarr 1971). Dendrochronological analyses were carried out for the dating of timber and were supplemented by AMS single and AMS 'wiggle matching' radiocarbon dating (Bronk Ramsey et al. 2001; Bronk Ramsey et al. 2010; Galimberti et al. 2004; Reimer et al. 2013), given as 2σ calibration ranges. Wood charcoal samples were taxonomically analysed according to their anatomical characteristics (Schweingruber 1990a,b). Charcoals were analysed on freshly broken surfaces with a stereo-lens with 5–100x magnification and an episcopic light microscope with 100–500x magnification and additionally their diameter was measured (Nelle 2002). Sediment cores up to several meters in length were taken in mires and depressions to answer geomorphological and pedological questions.

§ We would like to thank Dieter Allgaier, Elisabeth & Hans Rainer Bernhard, Erhard Bolender, Peter Feuerstein, Hans Helber, Christine Menge, Stephan Wiltsche and Philipp Scheitenberger. Special thanks go to Berthold Büchele, who contributed with his special expertise on historical contexts, and Franz Hau for important discoveries and tireless commitment.

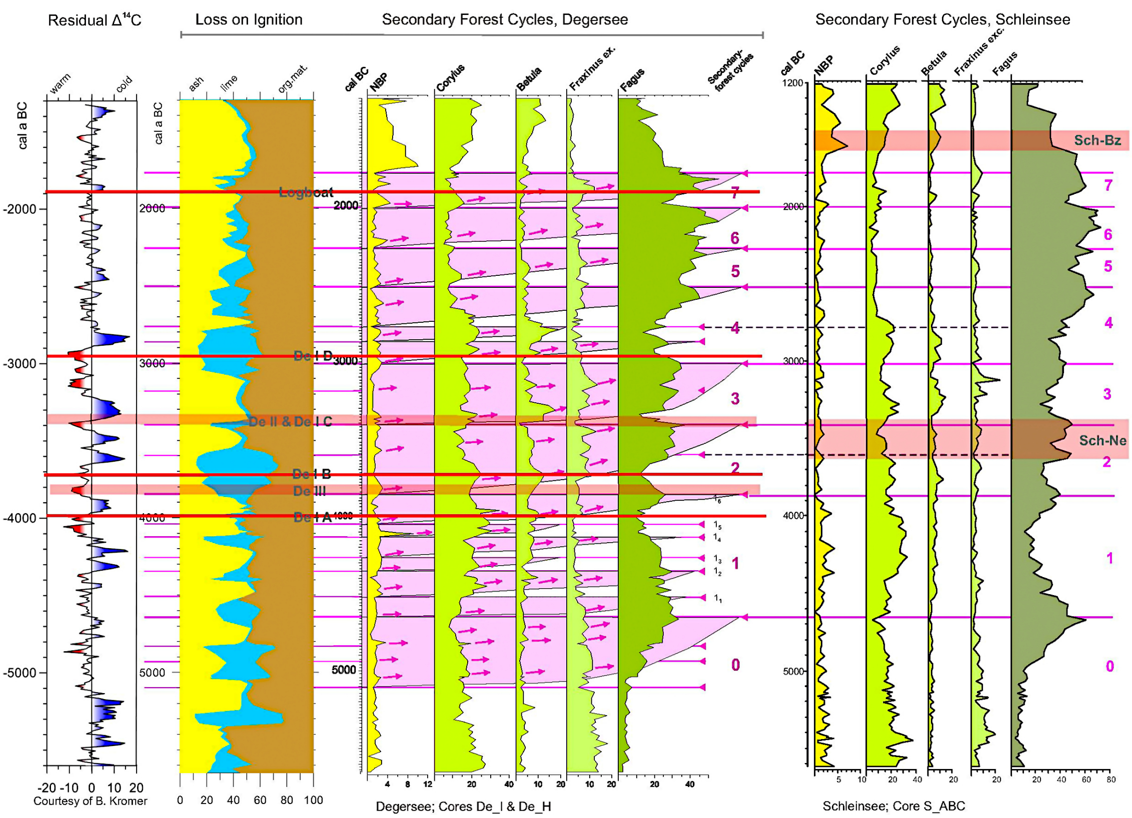

Figure 2: Synoptical diagram: Solar activity, loss-on-ignition, Neolithic occupations (DeI A–D, De II, De III and Sch-Ne) and Bronze Age evidence from Degersee and Schleinsee (red lines/bars). Comparison of pollen diagrams of the Neolithic Secondary Forest Cycles (magenta) in the sediments of Degersee and Schleinsee (Kleinmann, et al 2015, Abb. 29, modified).

First results

Off-site studies

Off-site studies were carried out at Schleinsee and Mittelsee. Both lakes are of glacial origin. Schleinsee is situated at 474 m asl close to the Degersee sites I to III. Recently a prehistoric site has been discovered in Schleinsee itself (Figure 1, 2). Mittelsee is located some 12 km to the northeast at 542 m asl and about 6 km away from the nearest known prehistoric site.

Cyclical oscillations of the climax beech (*Fagus*) forest were found in the Neolithic sediments of the three lakes studied (Kleinmann et al. 2015; H. Müller 1962, 1973). Müller 1973 interpreted these oscillations as 'secondary forest cycles' resulting from human activity. A secondary forest cycle starts with a decrease in *Fagus*, at the same time non-arboreal pollen (NAP) increase slightly. This phase is followed by an increase in light-demanding species such as hazel (*Corylus*) and birch (*Betula*) and succeeded by ash (*Fraxinus*). At the end of the cycle beech culminates again in a climax forest. Seven main secondary forest cycles could be identified. These secondary forest cycles are sometimes subdivided into subcycles, when the growth-cycle was interrupted by further clearing events (Fig. 2).

Schleinsee

Much data about this lake has already been accumulated but reliable AMS dating had not been available until now. Pollen analysis, loss-on-ignition, and thin section studies of the new core S_Y have been completed, AMS dating of this core is in progress. A few wooden piles retrieved by archaeological divers are dated to Neolithic and Bronze Age periods and prove the activities of settlers from 3625–3373 cal BC (Sch - Ne) and 1622–1510 cal BC (Sch - Bz; Fig. 2). When comparing the pollen peaks of beech from the so far undated Schleinsee core S_ABC with the corresponding peaks from the Degersee there is a perfect matching pattern when tentatively adjusted to the AMS ages of their partner peaks in Degersee (Fig. 2).

During the Degersee project, at the DeI site (Figure 3), five lakeshore occupations could be verified and dated. They all coincide with sediment portions characterised by the beginning of beech forest depressions, low lake levels, the accumulation of laminated calcareous mud and high solar activity as seen in the curve of residual delta ^{14}C (Figure 2). Peaks of the recovering beech forest, in contrast, coincide with high lake levels, 'weak sun', less charcoal, and massive diatomaceous non-calcareous mud (Figure 2) (Kleinmann et al. 2015). This coherent concert of processes and proxies implies an independent regional agent such as climate influencing environment and related human activity (Mainberger et al. 2015a, pp. 532–533).

Mittelsee

Mittelsee, situated about 12 km northeast of Schleinsee, resembles Schleinsee in size and morphology. No prehistoric settlements have been found on its shores or in the vicinity up to now. It has neither surficial inlet nor outlet, but is fed by groundwater from the surrounding gravel beds. Consequently, it is most appropriate as a reference lake for our on-going study. The lake is about 4 m shallower than Schleinsee and more exposed to the wind due to poor morphological shelter.

Preliminary testing/analyses and XRF scans in 200 µm steps showed that despite exposure to the wind the deposition during the Neolithic is characterised by sections of perfect and stable calcareous laminations, only interrupted by abrupt but short-span phases with a total lack of calcite, prevailing organic matter, and diatom silica. At the onset of the Bronze Age the sedimentary system changes within a few years: olive-coloured, sticky and massive mud completely devoid of calcite is dominated by diatoms and organic matter indicating an intense change in the economic system in the catchment of the lake, corroborated by elevated and fluctuating concentrations of titanium. There are virtually no terrestrial macroremains left in this upper core section that could be cleansed for AMS dating.

The palynological study is in progress. As expected, the secondary forest cycles begin to appear. Compared to the cores from Schleinsee and Degersee, the general frequency and density of a beech-dominated woodland seems to be higher with less distinct fluctuations and lower amplitudes in the characteristic cycles.

On-site studies

In the context of the BeLaVi project three so far unknown sites (Neukirch, Bodnegg, Leutkirch) have been confirmed as Neolithic sites with one or several occupations each. A considerable number of additional sites have delivered Neolithic materials or datings but hitherto no detailed evidence of their character (Figure 1). For many sites the only knowledge we have so far is that they are of prehistoric origin. Analyses and some fieldwork are still on-going. The following reports are therefore to be understood as tentative, with some examples highlighted, some general observations and lines of interpretation summed up in the discussion.

The lakeshore settlement at Degersee II

Degersee II (De II) is situated on the northern shore of Degersee, a small lake basin of glacial origin between Lake Constance in the south and the river Argen to the north (Figure 3). The lake is situated at 478 m asl, the terrain being about 80 m higher than Lake Constance. From 2008 to 2010 it was surveyed as part of the Degersee research project (Maier et al. 2010; Mainberger et al. 2015b). At present we know of three Neolithic sites on the lakeshore (Degersee I, II, III). With a Neolithic and a Bronze Age site at Schleinsee and colluvial deposits of the same periods at different sites in the vicinity, the Degersee-Schleinsee microregion (Figure 1) is one of the hotspots of the BeLaVi project.

The southern part of the De II site is today situated below the water table at a depth of about 1.5–2.5 m. Further to the northwest, piles and cultural layers are embedded in a peat moor that expands from the water line to the edge of the moraine hills. Drilling activities and excavation works were carried out in open water (trench 2, Figure 3), in the lacustrine and telmatic deposits of the mire (trench 4) and also on the mineral soils of the moraine, combining wetland archaeological and diving archaeological methods with investigations on dry land. In total, todays´

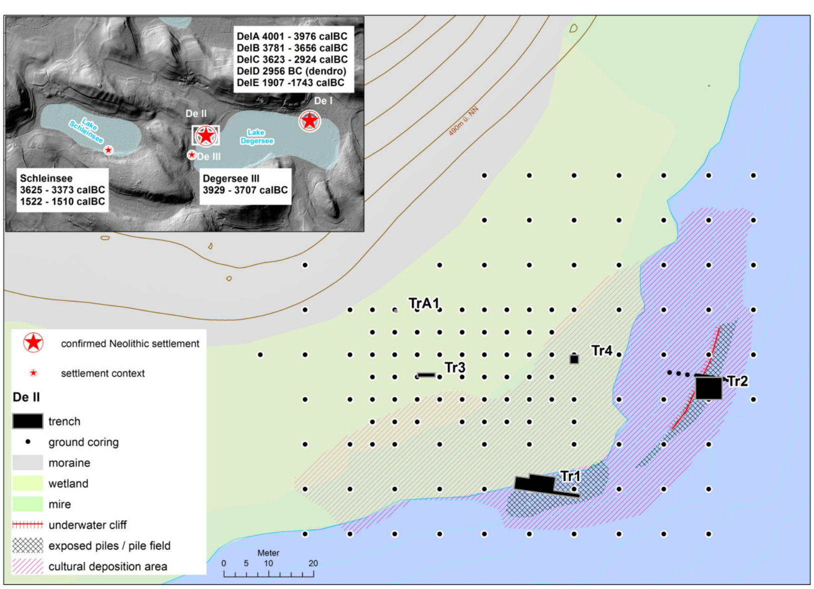

Figure 3: De II: General plan. Overview map: sites and datings in the Schleinsee/Degersee region (exclusive of De II). AMS radiocarbon dates are given in 2σ calibration ranges.

Figure 4: De II: Profile at the submerged shelf at trench 2. Photograph courtesy M. Mainberger / LAD.

knowledge of the site is based on 76 m^2 investigated by surface analysis, 13 m^2 excavated completely and 168 drillings.

Cultural layers are generally situated directly on top of the biogenic chalk of the Holocene lake. Sloping slightly down in southerly directions, they are covered by peat in the moor environment and by lake marl towards the lake. The southern, lakeside outer border of the site is marked by a geomorphological peculiarity. Anthropogenic remains stop in a sharp line formed by a submerged shelf, which rises about half a meter from the lake bottom, exposing culture layers in an almost vertical profile (Figure 4). Very few piles appear beyond this line. There are strong indications that the formation of this geomorphological anomaly is not a mere product of recent erosion processes but has its origin in the occupation period or soon after (Kleinmann et al. 2015, pp. 428–429). According to the results of drill cores, a similar geomorphological step occurs at the opposite side of the site, directly below the flanks of the adjacent moraines. Consistent results of plant remains analysis and on-site pollen investigations show that the cultural layer and natural deposits were intermittently influenced by high water tables.

Figure 5: De II: implements for textile production. Foreground: spinning whorls (trench 4); background: loom weights (trench 2). Photograph courtesy M. Erne / LAD.

This evidence, along with the stratigraphic position of the cultural layer directly on top of lacustrine sediments and also the total lack of any coherent constructions suggest that the houses on the site were not founded directly on dry ground but rather a bit elevated above the wet, soft, and at least periodically submerged conditions of a reed belt. Lake level fluctuations in combination with accumulation of lake sediments — as indicated in the pollen record — may have been the cause for the destruction and subsequent conservation of the site.

Cultural layers consist mainly of organic detritus, charcoal, charred and waterlogged timbers, pebbles, and clay. The artefact inventory contains ceramics, fired clay, stone and flint artefacts, and also the whole spectrum of waterlogged materials like wooden objects, seeds or animal bones.

Figure 6: De II: linseed (Linum usitatissimum). These seeds from the small-seeded flax types are only 2.7–3.0 mm long. Photograph courtesy U. Maier / LAD.

Table 1: Degersee II: Remains of crop plants.

	rest types	number	
common flax	seeds, capsule segments	28713	*Linum usitatissimum*
common flax	seed-, capsulefragments	++++	*Linum usitatissimum*
common flax	stem fragments	++	*Linum usitatissimum*
durum-wheat	chaff, grains	998	*Triticum durum*
barley	chaff, grains	102	*Hordeum vulgare*
emmer	chaff, grains	54	*Triticum dicoccon*
einkorn	chaff, grains	24	*Triticum monococcum*
wheat species	different remains	88	*Triticum sp.*
cereal species	different remains	1055	*Cerealia*
opium poppy	seeds	7041	*Papaver somniferum*
garden pea	pod fragment	1	*Pisum sativum*

Most prominent are finds connected to textile production, among them loom–weights (trench 2) and spinning whorls (trench 4; Figure 5). The loom–weights – a concentration of at least 7 objects of two different types – were embedded in a concentration of flax stalks, indicating an activity zone connected to textile production. Typological features of ceramics are best compared to sites dating about 3300 BC (Mainberger 2015, pp. 106–107). This matches with the absolute dates. Radiocarbon dates from construction timbers and from seeds cover the period between the end of 34th century until the 31th century BC (3339–3031 cal BC; 3331–2936 cal BC; 3348–3098 cal BC; 3338–3029 cal BC, 2σ). Dendrochronological dating has not been successful so far. Remarkably, radiocarbon dates of the neighbouring site Degersee I (De I) phase C indicate settlement activities at the same time period (Million and Billamboz 2015).

Agriculture, according to archaeological observations, seems to have been mainly based on common flax (*Linum usitatissimum*). Of the analysed plant remains this crop is absolutely dominant with nearly 30,000 remains, mainly uncharred seeds and capsule segments, an innumerable amount of very small fragments and a lot of stem parts (Figure 6; Table 1). It is a flax variety with small seeds with an average length of 2.9 mm (range: 2.6–3.1 mm), which only occurs from 3400 cal BC onwards. All flax seeds from older lakeshore settlements are distinctly bigger. It is assumed that the big-seeded flax was mainly used for its oil-rich seeds, while the small-seeded variety provided better fibres for textile production (Herbig and Maier 2011).

Compared to flax, cereals, with only about 2,300 remains (mainly uncharred chaff) seem to be of less importance. Most of the cereals are durum wheat (*Triticum durum*-type), a smaller proportion consists of barley (*Hordeum vulgare*), emmer (*Triticum dicoccum*), and einkorn (*Triticum monococcum*). The combination of a small-seeded flax variety and durum wheat as the dominant cereal is typical for the last quarter of the 4th millennium BC. The same evidence has been observed at approximately contemporary sites like Arbon Bleiche 3 (Hosch and Jacomet 2004), Bad Buchau Torwiesen II (Maier 2011), and Sipplingen-Osthafen layer 11 (Maier n.d.). More than 7,000 uncharred seeds of opium poppy (*Papaver somniferum*) prove the importance of this crop plant in the site. It might have been used as a medicinal plant or a drug, but the seeds can also be used for food.

In definite contrast to both the archaeobotanical observations and the archaeological record, flax cultivation is not well represented in the pollen data: five pollen samples taken from cultural sediments rich in flax macroremains contain only 0.1 – 2.0 percent *Linum* pollen. The anthers of *Linum usitatissimum* drop off during the ripening of the capsule. This, combined with the rather low pollen production, may be the reason for the poor reflection of flax processing in the pollen record. The same applies to the poppy, which is represented only by some single pollen grains of the *Papaver rhoeas* type that includes *P. somniferum* and the weed *P. rhoeas*. The pollen spectra of the cultural layers in the two profiles analysed from De II are characterised by high percentages of cereal pollen and indicators for gathering wild plants (rose hip, berries etc.).

Charcoal spectra from De II are dominated by alder (*Alnus*), ash (*Fraxinus*), and hazel (*Corylus*). Beech (*Fagus*) plays a significant role. Six other taxa are present, notably fir (*Abies*), which was also found once in the waterlogged branch wood spectra of De I (Million and Billamboz 2015, p. 300) and also in the timbers of De II. Waterlogged timber is clearly dominated by alder, followed by ash and beech. Overall, wood and charcoal show relative similarities, which indicates that the selection of construction timber was not thorough and did not exclude taxa which appear in the fuel wood spectra. The virtual absence of oak (*Quercus*) in the waterlogged samples of De II is striking and forms a strong contrast to pollen data (Kleinmann et al. 2015). It seems that either oak trees were virtually lacking in the close vicinity of the settlement or were not used for unknown reasons. Lime (*Tilia*) is present in charcoals, but rare in construction timber. Being a soft wood, it was probably predominantly used as fuel wood or for making wooden artefacts (which might have been burnt in the fireplaces once broken or no longer used).

Alder, ash, and beech pile wood samples with more than 20 tree rings were measured. They show an average of around 30 rings (alder, ash) and 40 rings (beech). So far, it was not possible to date them absolutely by dendrochronology due to the small number of rings and the problems of dating these wood species. However, some of the dendro curves match dendrotypologically (methods see Billamboz 2014) and form dendro-groups in the respective species of alder and ash. Most of the alder trees were cut in the same year; this can be said also for most of the ash trees. But the cross-dating of the two species was not possible yet, which means that there are no hints of the usage of alder and ash trees at the same time. Thus, it remains unclear whether there were one or two cutting phases at this site.

During the excavations at De II from 2015 to 2016 a total of 589 animal remains were recovered in trench 4. Together with the 522 bone objects excavated in 2009 in trench 1 (Stephan 2015) the archaeozoological sample now encompasses more than 1,100 bone fragments. Unfortunately, due to very high fragmentation and the substantial amount of very small fragments, only 8.5 percent of the bone finds could be determined to species level (number of identified specimens NISP = 94). In weight this identifiable percentage is equal to about 91.5 percent of the assemblage. Cattle and red deer finds predominate with approximately 25 percent and 40 percent of the identified specimens (40 percent and 30 percent by weight). Sheep or goat, pig, and dog as well as roe deer, wild boar, and red fox are represented by only few or single finds. According to this evidence, cattle breeding and hunting of red deer might have been important aspects of subsistence. Livestock breeding is also indicated by spores of coprophilous fungi and plants known to be used as winter fodder such as ivy (*Hedera helix*) and mistletoe (*Viscum album*). This taxonomic composition resembles the compositions of the faunal assemblages from contemporaneous sites such as Arbon Bleiche 3 (Deschler-Erb and Marti-Grädel 2004) and Sipplingen-Osthafen layer 11 (Steppan 2004, n.d.) but the number of identified specimens from De II is too low to make any reliable statements.

Taking all available information into account, De II represents a type of site we know from many shores and shallow water zones at pre-alpine lakes. Similar to the conditions in De I, it was built directly on the waterfront with houses slightly elevated from the wet surface. According to archaeological and absolute data the site dates to about 3300 BC or shortly after. Similar to other sites of that time, the cultivation of flax and textile production played a dominant role, with cereal and poppy cultivation, animal husbandry, hunting, fishing, and gathering being other important parts of economic subsistence.

The moor site of Bodnegg

The site at Bodnegg-Breites Ried is located some 20 km north of Degersee at 574 m asl. (Figure 7). A post-glacial backwater valley subdivides the Bodnegg microregion from drumlin formations north of the river Argen with the newly discovered site of Neukirch in its center. The heights of the inner terminal moraine are nearby to the north (Figure 1). The site was discovered in 2014 when waterlogged timbers, charred seeds, and artefacts were observed close to recently cleaned drainage ditches (Mainberger et al. 2016, p. 41). The subsequent archaeological surveys in 2015 and 2016 included establishing a coring grid consisting of 119 drillings, a georadar investigation and excavation of two small trenches.

Geomorphological and stratigraphical evidence result mainly from sediment coring. The profiles demonstrate that today´s meadows, pastures,

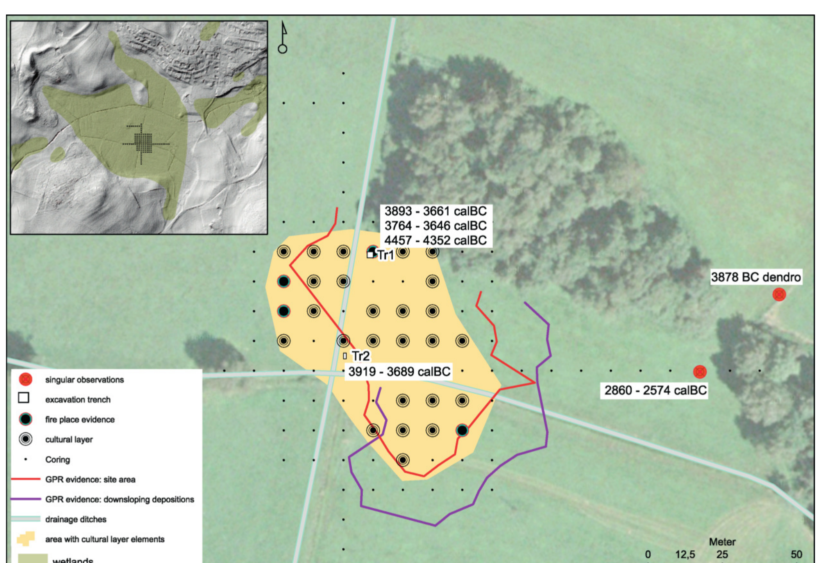

Figure 7: Bodnegg: General plan. AMS radiocarbon dates are given in 2σ calibration ranges. The given dendro-date refers to the last measured ring.

Figure 8: Bodnegg: fireplace in trench 1. Photograph courtesy H. Nagler.

and wetlands originate, like Degersee, in a glacial lake basin. The detected archaeological site is situated on top of peat layers in the centre of the mire. Glacial deposits and Holocene lake sediments are sloping down in away from the site all directions, forming an elevated plateau with cultural layers on top. Whether the peat mound was surrounded by open water at the time of human occupation, remains unresolved so far. However, the existence of organic lacustrine sediments on the periphery of the site indicates that its outskirts were strongly influenced by water.

In trench 1, a massive structure made of pebbles and clay was found below the sods of the surface (Figure 8). In the profiles the stratigraphy displays the detail. We know such structures from Neolithic and Bronze Age houses; there is no doubt that the trench cuts through a fireplace laid out on an earthen house floor. Due to poor organic conservation no wood has been conserved below this construction. Horizontal timbers in trench 2, however, suggest that floors made of timbers and clay were laid out directly on the peat surface. According to waterlogged wood analysis, oak and ash were used for the pile foundations of the houses.

Results from georadar allow us to distinguish mineral (clay) bodies and larger single stones from organic layers and help to indicate the outer borders of the site. The respective mapping correlates well with the drill core evidence. According to this evidence, houses were built in a total area of about 4000 m^2. Observations of down-sloping strata suggest a possible peninsular situation. A direct stratigraphical connection of this evidence to the detected clay floors has yet to be confirmed.

Due to short tree ring sequences of woods in the culture layer dendrochronological dating has not been successful so far. Radiocarbon samples taken from the fireplace in trench 1 date the detected culture layer to the 38th or 37th century BC. This dating well matches the excavated archaeological materials, which show close similarities to neighbouring cultural formations labelled ‘Pfyn-Altheimer Gruppe Oberschwabens’ or ‘Pfyner Kultur’. There are, however, distinct differences to these archaeological cultures as well. In trench 1 a representative archaeobotanical sample (57 x 20 x 12 cm) was taken. Within the cultural layer, a lot of cereal chaff and one flax seed (*Linum usitatissimum*) have been found among the

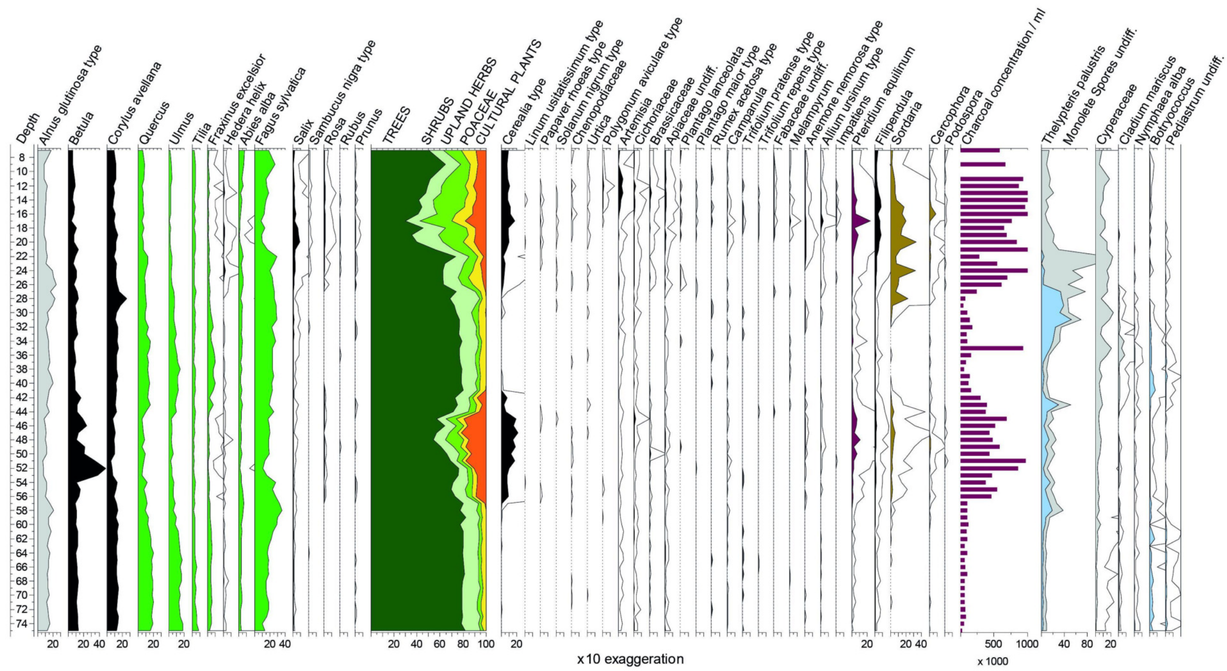

Figure 9: Bodnegg: on-site pollen diagram (trench 2) showing two Neolithic cultural layers separated by aquatic-telmatic sediments. Percentage values of major taxa and non-pollen palynomorphs (NPP); *Alnus*, aquatic plants and NPPs are excluded from the reference sum.

carbonised materials. 50 percent of the chaff was from einkorn (*Triticum monococcum*), nearly 30 percent from naked wheat (*Triticum durum-type*), and more than 20 percent from barley (*Hordeum vulgare*). This assemblage is different from those of comparable Pfyn-Altheim sites; in Reute-Schorrenried (Hafner 1998) and Ödenahlen (Maier 1995) durum-wheat was the prevailing cereal. The same sample was used for analysis of pollen and non-pollen palynomorphs. No pollen is preserved in the top 20 cm below surface as a consequence of the peat mire drainage. In the better preserved lower parts of the sample high percentages of cerealia pollen and sporadic finds of flax (*Linum usitatissimum* type) and poppy (*Papaver rhoeas* type) occur as well. Livestock breeding is represented by grazing indicators and spores of coprophilous fungi.

Charcoal spectra of the upper cultural layer in trench 2 are clearly dominated by beech, followed by oak, alder, ash, and hazel. This is in line with the assumption that the lake was small during Neolithic times and the woodlands on wet soils on its periphery were smaller or even non-existent compared to De II. The data suggests that Neolithic settlers collected their firewood further away, eg. on the surrounding minerotrophic soils.

There are strong indications that the 38th/37th century occupation represents not the only presence of farming communities at the site. The most distinct hint for an occupation dating about one century earlier was detected in pollen evidence originating from the lower part of the profile in trench 2; pollen and microcharcoal records reveal clear signs of nearby or on-site human impact (Figure 9). An oak timber sampled in the peat-gyttja deposition, which also contained some larger pebbles, dates to the 40th century BC (AMS radiocarbon). Additional evidence from the 38th/37th century was detected on the periphery of the cultural deposits. A radially split oak timber found in a trench gave a heart wood date around 3858 ± 10 BC (*terminus post quem*), and an alder wood from a coring was dated to 2860–2574 cal BC.

A palynological observation found some centimetres below the fireplace sequence of trench 1, where up to 2 percent cerealia pollen and a conspicuous increase in microscopic charcoal coincide with declines in pollen percentages of elm and ash was most surprising. A combination of several indicators like this leaves no doubt that there was human occupation in the near vicinity. According to a radiocarbon date of terrestrial plant remains in the peat formation this presence dates to the middle of the fifth millennium BC (4457–4352 cal BC) and is older than the earliest wetland settlements known in the Lake Constance region. This evidence was not observed in the stratigraphy of trench 2, which raises questions about the formation history of the respective sediment sequences. The pollen stratigraphy of trench 2 (Figure 9) reveals the great importance of animal husbandry by high amounts of spores of coprophilous fungi (*Sordaria*, *Cercophora*, *Podospora*) as well as the use of wild fruits/berries and herbs, such as *Filipendula* (meadowsweet) and *Pteridium aquilinum* (bracken).

Summing up, it can be tentatively stated that Bodnegg represents a moor site (*Moorsiedlung*), a settlement type we know from different periods of the north alpine Neolithic and Bronze Age.

Archaeological, geostratigraphical, and botanical observations suggest that we are dealing with a village that was erected on a peat mound in a wetland environment; whether it was surrounded by water at times or even permanently remains unresolved. The dimensions and numbers of houses are still unknown. Absolute dates and archaeobiological evidence indicate that the 38th century site had precedents in the centuries before and followers in the subsequent millennium; further investigations are necessary to precisely date and localise these occupations.

The hilltop site at Leutkirch-Wilhelmshöhe

Wilhelmshöhe is a hill above the town of Leutkirch. It is located at 707 m asl and rises from the banks of the river Eschach, a tributary of Iller and Danube (Figure 1). The site was discovered in 2014 during maintenance works at the public fairground (Mainberger et al. 2015b, p. 41). The elevation model (Figure 10) indicates that the hilltop, today perfectly flat, has been shaped by modern levelling works.

The Leutkirch area, in contrast to the microregions to the west, is a landscape characterised by fluvial waters rather than by bogs and mires. It has been subject to archaeological surveys since the 1930s, when Count Christoph von Vojkffy, an amateur archaeologist, detected a number of Mesolithic sites. Today we know that the respective inventories also contain a wide variety of Neolithic materials, some of them dating back to the Early Neolithic (Gehlen and Schön 2011).

Archaeological observations on Wilhelmshöhe were restricted to a few hours only and carried out by a volunteer. In the profiles and at the bottom of about 1 m deep ditches dark discolorations were found which proved to contain charcoal, charred seeds, stone and flint artefacts, ceramics, and burnt clay.

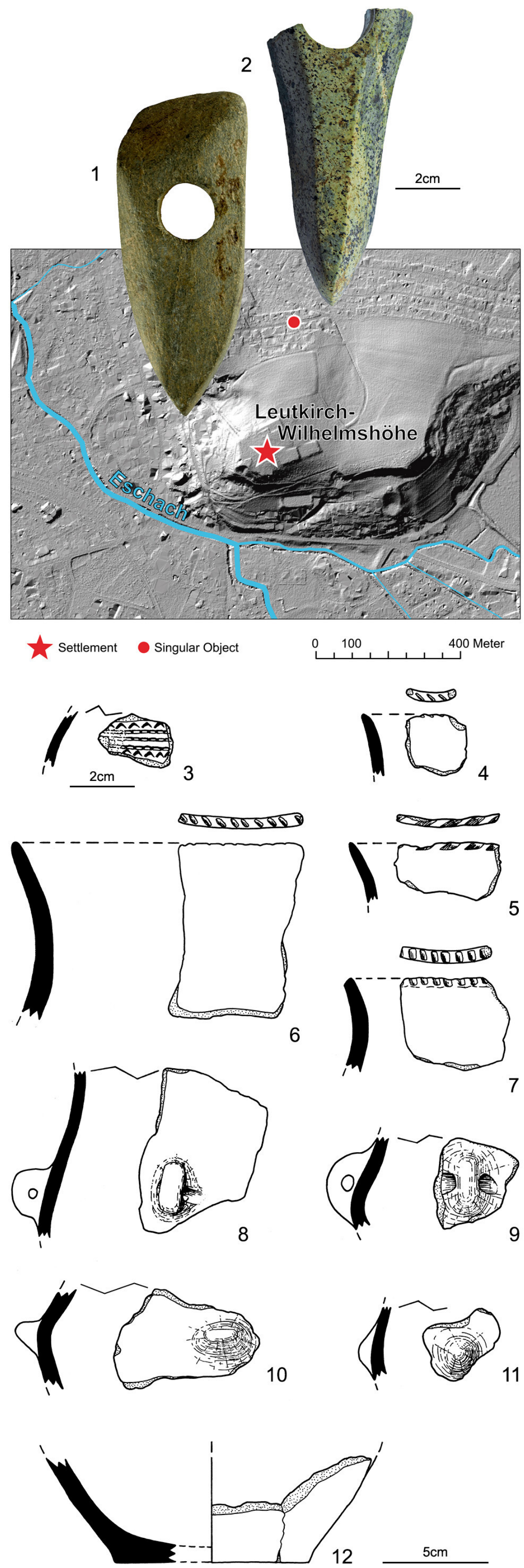

Figure 10: Leutkirch – Wilhelmshöhe: objects and elevation model. LIDAR data courtesy Landesamt für Geoinformation und Landentwicklung Baden-Württemberg; Photograph courtesy M. Erne / LAD; Drawings Ph. Gleich / LAD.

From the dimension and shapes of the evidence, it becomes clear that we are dealing with pits, indicating a permanent occupation. The archaeological finds can well be compared to the period of the earliest wetland sites from around 4300 cal BC onwards. The best affinity is to materials from Aichbühl (K. Müller 2000; Strobel 2000, pp. 223–224) and Schulterbandgruppen (SBK) (Zeeb 1998). A radiocarbon date derived from charred seed (4345–4251 cal BC) confirms this archaeological and chronological context. Aichbühl, with its eponymous site in the Federsee basin, marks the beginning of the lake dwelling tradition in southwest Germany (Strobel 2000, p. 438). Hitherto the eponymous site was the southernmost settlement in the Aichbühl Culture, which has its main distribution area along the Danube and its tributaries (see Mainberger 2015, pp. 97–98). The Leutkirch site, with its location at the western sources of the Danube hydrological system well matches this archaeological background.

Up to now 35 litres of sediment have been analysed botanically. Most of the 630 charred plant remains determined were cereals and field weeds. It revealed that einkorn (*Triticum monococcum*) was the prevailing crop with about 73 percent of the total inventory followed by emmer (*Triticum dicoccum*) with 20 percent. Naked wheat (*Triticum durum*-type) and barley (*Hordeum vulgare*) only played minor roles. The predominance of einkorn is typical for this time span. It can be found in several synchronous sites attributed to the Schussenried culture of the Middle Neckar region (Maier 2004) as well as in the Degersee IA and Degersee IB sites (Figure 3) and at contemporaneous Federsee and Lake Constance sites (Billamboz et al. 2010; Maier 2015; Maier and Vogt 2004). Apart of the cereals, nearly 200 weed seeds were identified derived from at least 9 weed species. Most of them are from graminaceous plants (grasses) which imply the existence of fallows. Remains of non-cultivated plants were extremely rare in comparison to Degersee II and Bodnegg. Only hazelnut (*Corylus avellana*) has been identified with 8 shell fragments. However, as Leutkirch-Wilhelmshöhe is a mineral soil site, this may well be due to taphonomic reasons.

The lack of beech (*Fagus*) in the Leutkirch charcoal spectrum is striking. Reasons for it are difficult to discuss in the absence of additional samples. However, the species assemblage matches the radiocarbon date very well with a significant presence of elm (*Ulmus*) well before the elm decline.

Leutkirch–Wilhelmshöhe is geographically furthest advanced to the flanks of the Allgäu Alps and has the highest elevation of the Westallgäu sites presented here. In strong contrast to the Degersee and Bodnegg sites it is situated in a hilltop position and conserved under mineral soils. Nevertheless, it has distinct connections to water and the hydrological network: Wilhelmshöhe has a close spatial relationship to the confluence of the Eschach and Wurzacher Ach rivers and therefore a potential junction of routes between the Rhine river system, the inner Alps and the Iller/Danube catchment.

Archaeobotanical evidence and archaeological materials support the idea that the cultural connections of the site are oriented to the landscapes to the north. Due to the restrictions of a rescue activity carried out by a hobby archaeologist, many questions about this important site remain unresolved so far.

Preliminary conclusion and perspectives

Degersee II, Bodnegg, and Leutkirch represent a mere fraction of the more than 20 sites that have been surveyed or investigated so far. The lakeshore, moor, and hilltop sites indicate that the Westallgäu region offers a similar multitude and diversity of archaeological sources as their western neighbours, the well-researched archaeological landscapes of Upper Swabia and the Lake Constance/Hegau region. The origins and subsequence of cultural development follow more or less the same order and logic, with an initial episode around 4300 BC (Leutkirch) that is followed by occupations in the 40th century BC (Degersee I) and the 39th to 37th century BC (Degersee I, Degersee III, Bodnegg, Neukirch). A later occupation dating to the 36th or 35th century occurs in Schleinsee.

Degersee II, with dates at about 3300 BC, starts another well-represented period around the turn of the 4th to the 3rd millennium. Degersee I D, with dendrochronological dates at 2956 BC (Million and Billamboz 2015, p. 287), concludes this sequence. Hints on slightly later occupations (Bodnegg) match our knowledge of sites in the Schussen valley (Ravensburg-Veitsberg) and Upper Swabia. According to this data, during the Neolithic the Westallgäu region was closely connected to the cultural development in the landscapes to the west and southwest. The archaeological data is supported also by scientific evidence. Farming and woodland economy, which is complemented by hunting and gathering subsistence strategies, follow the same models we know from the archaeological landscape further to the west. Slightly deviating scientific evidence from Leutkirch, the easternmost, most elevated and hydrographically different site, implies variants of the respective patterns. However, this may also result from different taphonomic conditions of the archaeological evidence.

Neolithic Lake Constance and Upper Swabia have long been known as important melting pots for goods, ideas, and people. A distinct geographical axis (Alpine Rhine valley–Schussen valley–Federsee bog) connects huge areas to each other with the Alps and northern Italy to the south, the Rhine Valley to the west and the Danube to the north and east (Köninger and Schlichtherle 1999; Mottes et al. 2002). The archaeological prominence of the Federsee bog may well result from its position on top of the continental water divide, with riverine systems and traffic routes connecting to each other. The concentration of sites at the lower course of the Argen river and again at the upper courses of the Iller tributaries suggest now that the Westallgäu might have played a role in this system as well. The flanks of the Argen valley could have offered an alternative track and a direct route to the Iller. Such a connection and also direct routes along the northern foothills of the Alps or along the inner Alpine valleys have been long postulated (Kieselbach and Schlichtherle 1998, p. 181; Mainberger 2015, p. 114).

The new evidence raises questions on what happened further to the east. Although the gap between the newly discovered Westallgäu archaeological landscape and the contemporary sites in the Bavarian pre-alpine foreland (Pflederer et al. 2009, p. 132; Schönfeld 2001, p. 18) has become smaller, the large area east of the BeLaVi study area still has archaeologically blank spaces at least during the Neolithic. Whether this gap is a mere product of current state of research or represents a prehistoric reality is still unresolved by the present state of research. The data presented here, albeit preliminary, confirm once more that empty spaces on Neolithic maps do not necessarily mirror any prehistoric reality. Furthermore, and other than postulated until recently (Schier 2009, pp. 19–20), relatively high annual rainfall and pre-alpine glacial landscapes have not been a barrier for the second wave of 'Neolithisation' from 4800 BC onwards. With a relatively low input in manpower and financial resources an impressive high output, not only of new sites but of evidence of a formerly completely unknown archaeological landscape, has been accumulated indicating that the area was as intensively occupied as the well-known regions and the UNESCO world heritage areas at the big lakes and large peatlands like the Federsee basin (Hagmann et al. 2011).

An important contribution to this success has been the combination of off-site and on-site data and the wide range of methods used, especially on-site palynology and macroremain studies linked to geomorphological analysis. High-resolution analyses of on-site pollen, microcharcoal, and non-pollen palynomorphs (NPPs) facilitated the detection and location of prehistoric occupations even where cultural layers could not be identified during excavation or in trench and drilling profiles. From an archaeological point of view, the most remarkable quality of the respective observations is their chronological age. Consistently the evidence of off-site pollen indicates Neolithic occupations long before the introduction of the lakeshore tradition into the pre-alpine foreland. Off-site palynological records expand this new knowledge to a landscape scale. We expect that the comparison of the Degersee and its known Neolithic sites with the evidence from nearby Schleinsee and Mittelsee will enable us to find arguments to distinguish human impact from natural processes.

The BeLaVi Westallgäu project will continue until 2018. The focus will be on the analyses of archaeological and scientific fieldwork and synthetic work with the results of the Swiss and Austrian research groups. After each region has precisely discussed off-site and on-site results on human activity and suggested wider patterns of landscape change, the next step will be comparing and connecting of the results of all three regions in order to separate local from supralocal patterns and discussing supralocal players like climate vs. human settlement and demographic rhythms.

Tables

Table 2: Leutkirch – Wilhelmshöhe: carbonised botanical macroremains.

sample number		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**total**
sample vol. (litres)		**10**	**10**	**10**	**10**	**5**	**5**	**5**	**5**	**5**	**5**	
einkorn												
Triticum monococcum	grains	3	3	3	1	2	2	2	1	2	4	23
Triticum monococcum	spikelet forks	10	27	8	11	10	11	6	3	13	-	99
Triticum monococcum	glumes	7	33	8	20	9	5	9	2	-	31	124
emmer												
Triticum dicoccum	grains	-	1	-	3	2	1	-	-	-	-	7
Triticum dicoccum	spikelet forks	2	4	1	5	2	1	-	2	3	-	20
Triticum dicoccum	glumes	-	9	3	10	5	3	1	2	-	3	36
naked wheat												
Triticum aestivum/durum	grains	2	4	2	-	-	2	3	2	-	1	16
Triticum aestivum/durum	internodes	1	-	1	-	2	-	1	-	-	5	10
barley												
Hordeum vulgare	grains	1	-	-	-	-	-	-	-	-	1	2
emmer/einkorn												
Triticum dicocc./monococc.	spikelet forks	-	-	1	-	1	-	1	-	-	3	6
Triticum dicocc./monococc.	glumes	-	4	-	13	8	3	3	-	2	2	35
wheat species												
Triticum sp.	grains	-	-	1	3	3	1	-	-	2	4	14
Triticum sp.	internodes	-	-	-	-	-	-	1	2	-	-	3
Triticum sp.	glumes	-	-	-	-	-	-	-	1	-	-	1
cereal species												
Cerealia	grain fragments	10	9	18	15	16	17	22	3	11	15	136
Cerealia	grains	3	2	4	-	-	2	3	6	2	2	24
Cerealia	embryo	-	-	-	-	-	-	-	-	1	1	2
weeds												
Bromus secalinus	seeds	-	1	-	-	-	-	-	-	-	-	1
Bromus sp.	seeds	2	2	-	-	-	1	-	-	-	-	5
Bromus sp.	seed fragments	-	-	-	2	-	-	-	1	-	-	3
Chenopodium album	seeds	-	-	-	3	-	-	1	-	-	1	5
Chenopodium album	seed fragments	1	1	4	2	-	-	-	-	-	-	8
Chenopodium polyspermum	seeds	1	-	-	-	-	-	-	-	-	-	1
Chenopodium sp.	seeds	-	-	1	-	1	-	-	-	-	-	2
Fallopia convolvulus	seeds	4	5	11	6	4	7	1	3	3	8	52
Fallopia convolvulus	seed fragments	4	31	-	4	-	-	5	1	-	-	45
Galium sp.	seeds	1	1	-	-	-	-	-	-	-	-	2
Lapsana communis	seeds	1	-	1	-	1	-	-	-	1	1	5
Poa annua/Phleum pratense	seeds	1	-	-	-	-	-	-	-	-	-	1
Poaceae, kleine	seeds	9	13	22	19	9	5	-	1	4	2	84
Silene vulgaris	seeds	-	1	-	-	-	-	-	-	-	-	1
Stellaria media	seeds	1	-	-	-	-	-	-	-	-	-	1
collected plants												
Corylus avellana	shell fragments	4	2	-	-	1	1	-	-	1	-	9
various												
Luzula sp.	seeds	-	-	-	-	-	1	-	-	-	-	1
Eupatorium cannabinum	seeds	-	-	-	-	-	1	-	-	-	-	1

Table 3: Percentage proportions of waterlogged wood and charred wood (char) at the sites at Degersee II (De II), Bodnegg (Bw) and Leutkirch-Wilhelmshöhe (LTKI). n = no. of analysed wood finds/charcoal fragments.

%	DeII					Bw		LTKI
		charcoal				char	char	char
	wood sum	1.1	3.3.1	3.3.2	wood sum	2.1	3.1	
Fraxinus (Ash)	31	16	20	19	28	5	13	27
Alnus (Alder)	44	13	22	17	17	24	4	.
Populus (Poplar)	.	6	11	6	.	.	.	.
Salix (Willow)	.	10	5	12	22	2	<1	.
Corylus (Hazel)	5	22	22	26	6	5	9	10
Acer (Maple)	3	10	1	3	.	15	5	15
Tilia (Lime)	1	17	6	3	.	2	3	.
Ulmus (Elm)	1	<1	.	1	.	.	.	4
Fagus (Beech)	13	4	13	14	17	22	44	.
Abies (Fir)	.	1	.	.	.	.	.	.
Quercus (Oak)	1	.	.	.	11	12	21	35
Betula (Birch)	.	.	.	.	.	5	2	.
Euonymus (Spindle tree)	.	.	.	.	.	7	.	.
Maloideae (Pomaceous fruit)	.	.	.	.	.	.	.	10
n	**149**	**300**	**116**	**200**	**18**	**41**	**200**	**52**

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From lakeshore to hilltop. Investigating Copper Age landuse in the Attersee-Mondsee region

12

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Introduction

The investigations presented in this paper are part of a trinational research effort tracing human-environment relations in the area of the northern Alpine lakes throughout the Holocene. The project 'Beyond Lake Villages' (BeLaVi) brings together research groups from Switzerland, Germany, and Austria within a transdisciplinary research framework. In three different research areas closely integrated archaeological and palaeoecological studies were conducted to investigate human-environment relations with special attention to the time period of the 4th mil. BC.

The Austrian part of the BeLaVi project focuses on the core area of the Mondsee group (Figure 1). Of Austria's nearly 30 waterlogged sites 22 are attributed to this cultural entity. These sites lie scattered around the lakes Attersee and Mondsee at the periphery of the Northern Limestone Alps. Together with the cultural entities of Cortaillod and Pfyn, the Mondsee group counts among the earliest copper-using horizon north of the Alps (Frank and Pernicka 2012; Ruttkay et al. 2004). The rich material culture of these lacustrine sites indicates a complex socioeconomic structure and farreaching transalpine contacts (Ruttkay et al. 2013, 2004). Within

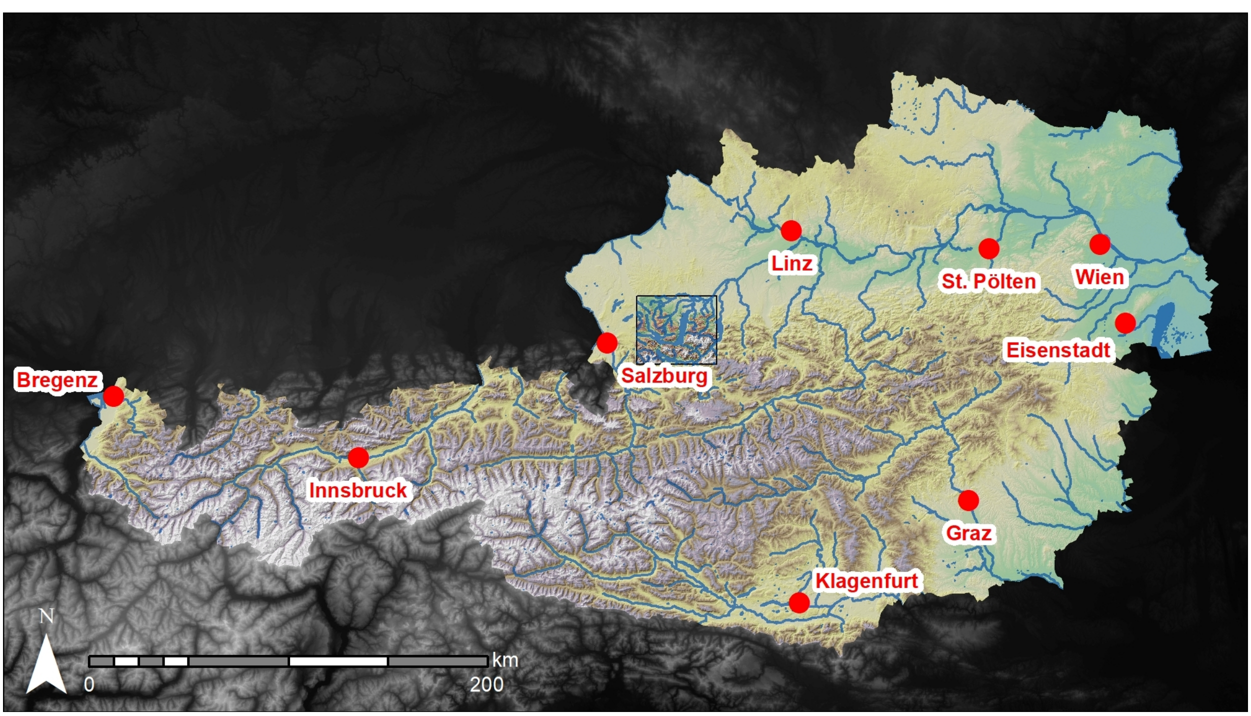

Figure 1: The resarch area of the BeLaVi Austria project is located on the northern border of the Eastern Alps in the historical Salzkammergut region. Data source: Land Oberösterreich, CGIAR-CSI, Geofabrik GmbH and Open Street Map contributors. Map author: Julia Klammer.

Kowarik, K., J. Klammer, H. Seidl da Fonseca, J. Maurer, T. Taylor (2020). 'From lakeshore to hilltop. Investigating Copper Age landuse in the Attersee-Mondsee region'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 233–250. DOI: 10.11588/propylaeum.714

the BeLaVi Austria project we aim at developing a more detailed picture through the investigation of landuse and human-environment relation. Our approach targets different spatial scales and perspectives by combining landscape archaeology research such as spatial analysis, LiDaR, and field survey with archaeological excavations and palaeoecological research focused on the establishment of highly resolved palaeoenvironmental records. In the present paper we discuss first results of our landscape archaeology work by adressing visual patterns, landscape characterization and site location choice.

State of research

The Mondsee Group

The geographical distribution of the Mondsee group is rather limited. Sites undisputedly attributed to this group are located in the northern Alpine foreland of Upper Austria south of the Danube between the Salzach valley to the East and the Enns valley to west. The core area of the Mondsee group lies in the southern part of this region and is constituted by 22 lacustrine sites on the shores of lakes Attersee and Mondsee. Sites with the distinctive Mondsee ceramic are distributed over a wider area from eastern Bavaria to Lower Austria to the southern alpine foreland in Styria (Buchvaldek et al. 2007, map 14a-15a; Ruttkay 1981, 1998; Maurer 2014, esp. Figure 1).[1] There are indications that the geographic distribution within the Mondsee group area might contain a chronological element, with sites attributed to an older phase (Mondsee 1) mainly known from dryland, whilst many of the younger phase sites (Mondsee 2) are located in the shore area of lakes Attersee and Mondsee (cf. Maurer 2014).

1: At present no burial sites are known.

Looking at site location choice of Mondsee settlements a certain variability is detectable, ranging from lake shores, to river confluences to elevated positions on hilltops (with larger settlement areas), and small cliffs. Jakob Maurer has recently drawn attention to the eastern periphery of the Mondsee area, reevaluating a small group of sites located 20 to 25 km east of the Enns valley (Maurer 2014, pp. 147–52). One of the most striking features of this group of small-scale settlements is a marked preference for small and steep rock cliffs offering only very limited settlement space (40 m^2 to 500 m^2). Some sites seem to have been settled during prehistory only in the 4th millennium, such as the small cliffs, others such as the hilltop settlement site of Ansfelden just south of the Danube, were settled throughout prehistory (Trebsche 2008). As to the lacustrine sites, in the course of the underwater excavation programme conducted by the Kuratorium Pfahlbauten and the Federal State Museum of Upper Austria since 2015 evidence for multiperiod settlement activity on the lake shore is emerging (Pohl 2015, 2016).

The typology of the Mondsee group was initially divided into three phases Mondsee 1-3 (Ruttkay 1981). At present, phases Mondsee 1 and 2 are considered to represent the actual Younger Neolithic Mondsee group, whereas Mondsee 3 could represent a local expression of Late Neolithic Cham (Ruttkay 1998; Ruttkay et al. 2004). Elisabeth Ruttkay pointed out strong correlations between Mondsee 1 and the young neolithic groups of Pfyn and Altheim and typological correlations between Mondsee 2 and early Baden (Boléraz phase) (Ruttkay et al. 2004, pp. 58–59, 2013, p. 247). In absolute terms the Mondsee group is currently dated from 3800–2900 BC, with Mondsee 1 and 2 falling between 3800 to 3100 and Mondsee 3 perhaps between 3100–2900 (Dworsky and Reitmaier 2004; Frank and Pernicka 2012; Krenn-Leeb 2006; Ruttkay et al. 2004, pp. 58–59). But due to the lack of closed finds the chronological framework remains coarse grained. At present the end of Mondsee 2 can only be dated to a time span between the 35th and 31st century BC. The chronological framework of the Mondsee group is based on unstratified materials from the lacustrine sites. In its foundations it relies upon the typochronological phasing of selected materials from the various lacustrine sites proposed by Elisabeth Ruttkay in 1981 (Ruttkay 1981). The absolute chronology is constituted of radiocarbon measurements (cf. Krenn-Leeb 2006; Ruttkay et al. 2004, 2013). The bulk of these samples were taken from wooden piles in the course of surveying campaigns during the 1970s and 1980s and the early 2000s (Dworsky and Reitmaier 2004; Offenberger 1981, 1986). Neither the archaeological materials nor the samples for radiocarbon measurements come from closed contexts. Until very recently no closed find contexts of the 4th millenium BC were known from the core area of the Mondsee group. Current research activities aim at developing a reliable and well resolved chronological framework.

The discussion of the economic and social structure of the Mondsee group is mainly based on the lacustrine sites. The idea that the communities living on the shores of lake Attersee and Mondsee were a central part of a transregional network and played an important role in the material flows of the wider region, especially copper, was proposed early on (Franz 1928). This model was based on topographic (hydrological network), geographic (proximity to copper districts in the Salzach Valley), and archaeological considerations (number of copper objects). Later on, this idea was heavily criticized also on the basis of topo-geographic considerations (Willvonseder 1963, pp. 8–12, 299–307). Willvonseder emphasized the low regional and transregional connectivity of the area and developed a model of mainly agrarian based farming communities. As in the following years underwater surveys increased the number of known sites and expanded the find inventory, it became ever more obvious that copper must have played an important role in the economy of the lacustrine communities (Obereder et al. 1993). In fact the Attersee-Mondsee region represents one of the densest find regions for 4th millenium copper objects and casting crucibles in Europe (Frank and Pernicka 2012; Obereder et al. 1993; Ruttkay et al. 2013, 2004). Currently about 70 copper objects and more than 160 fragments of casting crucibles are known (Obereder et al. 1993). Based on these observations Ruttkay et al. suggested a reevaluation of the economic and social structure of communities living on the lake shores (Ruttkay et al. 2004).

> 'The inhabitants of the pile dwelling settlements are generally referred to as "pile farmers". At Mondsee, this is not entirely accurate. The most famous elements of the archaeological record are the metal finds: in particular, the evidence of local copper processing.' (Ruttkay et al. 2004, p. 57).

The copper objects found in the lacustrine sites of the Attersee-Mondsee region are caracterized by 'a high arsenic (0,5 per cent to 5 per cent) content while antimony, silver, and nickel are only present in very low concentrations' (Frank and Pernicka 2012, p. 124). Objects with this composition have a wide distribution over Europe from the Carpathian region to Scandinavia and the Rhône valley (Gleirscher 2007, pp. 105–106; Krause 2003, pp. 147–160), but show a special density in the Attersee-Mondsee region as well as in Eastern Switzerland (Frank and Pernicka 2012; Matuschik 1997; Obereder et al. 1993; Ottaway 1982). The origin of this copper is yet unknown, but Caroline Frank and Ernst Pernicka have recently excluded the possibility of an eastern alpine provenance and pointed towards southeastern Europe as a possible area of origin (Frank and Pernicka 2012). The role of the Mondsee group and the Attersee-Mondsee region within this network is unclear for the moment. Apart from the copper objects, casting spills, and crucibles other material categories such as ceramics, silex, and archaeobiological materials suggest widespread contacts within and across the alpine zone, reaching as far as the middle Danube region (Maurer 2014, pp. 155–166; Ruttkay et al. 2004, 2013).

The research area: environmental characteristics and research history

The prealpine lakes Attersee and Mondsee are located in the alpine foreland on the northern border of the Eastern Alps (Figure 1, Figure 2). The area is part of the historical region *Salzkammergut* and connects two major natural regions, the alpine foreland to the north and the Limestone Alps to the South. The research area stretches around lakes Attersee and Mondsee. It can be subdivided into three zones running from North to South. The northernmost part is dominated by the hilly landforms of the alpine foreland and belongs geologically to the Molasse zone. End moraines and deeply incised river valleys (e.g. Vöckla, Dürre Ager, Ager) shape the landscape, which reaches maximal heights of 500 m. The southern border of this area runs just North of lake Attersee. The adjacent section belongs to the Flysch zone and makes up the largest part of the research area. The landscape is shaped by the large perialpine lakes (Irsee, Fuschlsee, Irrsee, Mondsee, Attersee etc.), end moraines, and the Flysch mountains. The height of 1000 m is only rarely surpassed. In the southernmost part of the research area the steep rock walls of the lime stone alps dominate.

About 70 lakes are known from the wider Salzkammergut region. Within the research area lie three of the largest (Attersee, Mondsee, Wolfgangsee) and roughly ten mid-size to small lakes (e.g. Irsee, Fuschlsee, Langbathseen). Lacustrine sites are only known from lakes Attersee and Mondsee. These form the chain of lakes Irrsee-Mondsee-Attersee strechting roughly from northwest to southeast to east. Irsee, Mondsee, and Attersee represent typical glacial lakes. Both lake Mondsee (16,6 km^2, max. depth 68 m) and lake Attersee (46,2 km^2, max. depth 169 m) are characterized by a gradual change from perialpine landforms in the northern part to alpine landforms in the South. Sheer limestone rock walls rise on the southeastern shore of Lake Mondsee and encompass the southern end of lake Attersee. On both lakes the areas directly adjacent to the lake shore are predominantly formed by steep slopes belonging either to the ridges of the limestone alps or in the northern part to Flysch mountains. Gently sloped shore areas and flat-open hinterlands are limited to the northwestern / northern part of lake Attersee and on lake Mondsee to its western end and a small stretch on the northern shore. Lake Irrsee (3,55 km^2, max. depth 32 m), the smallest in the lake chain, is located

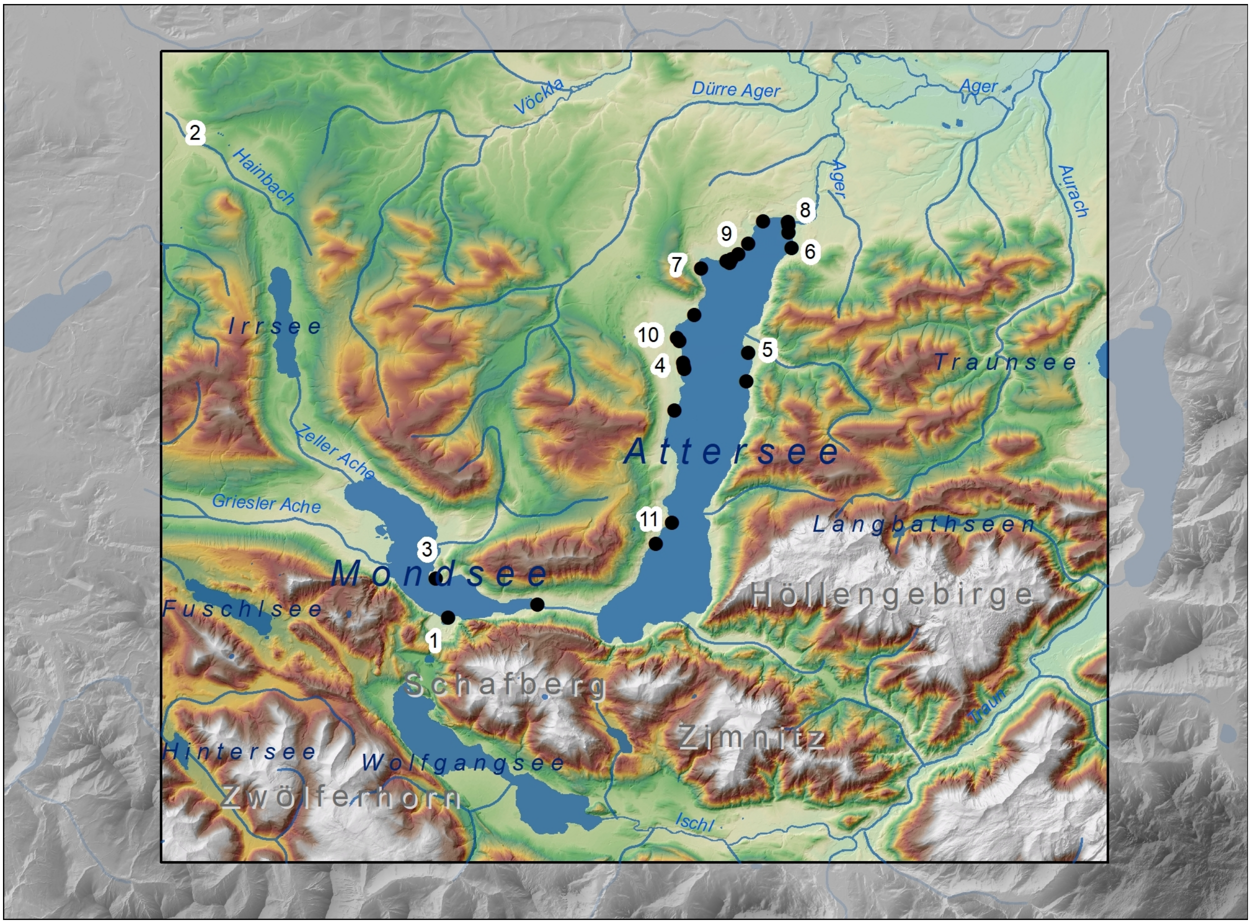

Figure 2: Research Area with all known lacustrine sites sites. Data source: Land Oberösterreich, CGIAR-CSI, Geofabrik GmbH and Open Street Map contributors. Map author: Julia Klammer.

entirely in the perialpine foreland. Amongst the area's numerous watercourses the Traun river and the Ager river are the most important. The Traun and its tributaries drain the entire Salzkammergut region and link it to the Danube valley. The Traun river only crosses the research area in its easternmost corner. The Ager river, one of its most important tributaries, is the dominant drainage system here (catchment area 1260 km^2). It is the sole effluent of lake Attersee. From lake Attersee the Ager runs Northeast into the Molasse zone and forms together with the Vöckla river the eastward running Vöckla-Ager valley in the northernmost part of the research area. About 30 km northeast of lake Attersee the Ager flows into the Traun river which in turn flows into the Danube. Whereas lake Attersee drains to the north into the prealpine foreland through the Ager river the other two lakes of the lake chain, Mondsee and Irrsee, drain to the South. Lake Irrsee's sole effluent, the Zeller Ache, connects Irrsee to Mondsee and lake Mondsee's only effluent, the Seeache, runs into lake Attersee. Thus through lake Attersee the Ager also drains lakes Mondsee and Irrsee. The Ager's most important tributaries Vöckla, Dürre Ager, and Aurach are typical Flysch zone rivers with strong seasonal changes in water volume.

For more than 130 years the research activity within the area has been focused on the lacustrine sites. The sites on the shores of lakes Attersee and

Mondsee make up the bulk of the 4th mil. site inventory in the research area (Figure 2). Of the 23 sites dated to the 4th mil. 22 are lacustrine sites. The first discoveries of lacustrine sites on Attersee and Mondsee were made in the 1870s (Ruttkay 1998). This initiated a period of intense interest lasting well into the first of half of 20th cent. A considerable number of sites were discovered. Objects were dredged up in large quantities by means of shovels, nets, and poles. Especially the site of See/Mondsee yielded a great number of finds. Comprehensive publications of the rich find materials first appeared for Mondsee in 1927 (Franz and Weninger 1927) and for Attersee in the 1960s (Willvonseder 1963). In 1969 the Federal Office for Monument Protection initiated an underwater survey programme (1969 to 1986). The project, headed by Johann Offenberger, involved surveying the lake shore for new sites, documenting and inventorizing the known sites, and retrieving characteristic samples of material culture as well as sampling for dendrochronological analysis and radiocarbon dating (Czech 1989; Offenberger 1986). During this time several research initiatives were launched (Offenberger 1986). These included a more detailed investigation of the site of See am Mondsee by means of a prospection trench. Here a considerable number of archaeological and bioarchaeological materials were retrieved. Palynological, sedimentological, and macro remain analysis were conducted on several on-site cores from the settlement sites of Weyregg I/Attersee, Aufham/Attersee, and See/Mondsee (Chondrogianni et al. 1986; Schmidt 1982, 1986). Especially the investigations on the See cores gave first insights into subsistence strategies and landuse (Schmidt 1986). After 1986 all survey and excavation activity came to a halt.

Between 1989 and 1995 an interdisciplinary research project headed by Elisabeth Ruttkay focused on the analysis of the find materials that had been retrieved from the Upper Austrian and Carinthian underwater sites until 1986 (Ruttkay 1995). For Upper Austria a study of the archaeozoological material from Lake Mondsee was published (Pucher and Engl 1997), as well as a catalogue of the ceramics from these sites (Lochner 1997), and a number of preliminary reports on various object categories appeared (Antl-Weiser and Holzer 1995; Antl-Weiser 2006; Obereder et al. 1993). In the early 2000s a renewed underwater survey programme aimed at inventorizing the known lakeshore sites and assessing the state of preservation (Dworsky and Reitmaier 2004).

One of the most important impulses for research on Austria's lacustrine sites came in 2011 with the conferral of UNESCO World Heritage status for 111 lacustrine sites around the Alps including five sites in Austria.[2] The conferral of World Heritage status led to the creation of institutional structures for management and monitoring of the World Heritage sites (Kuratorium Pfahlbauten) and engendered a new phase of research activity. In 2014 the University of Vienna started an excavation programme in the hinter-land of the lakes (Herzog et al. 2014, 2015). And one year later, in 2015, the Kuratorium Pfahlbauten and the Federal State Museum of Upper Austria initiated an underwater excavation programme, the Zeitensprung project, targeting the lacustrine sites in Lakes Attersee and Mondsee (Dworsky and Novak 2012; Pohl 2015, 2016). Both projects address one of the most pressing issues, namely the lack of large-scale excavations and subsequently the lack of well controlled and highly resolved chronostratigraphies. A new and more detailed picture is beginning to emerge. One of the most important findings of the dryland campaigns

2: Carinthia: Keutschacher See, Upper Austria: Attersee: Abtsdorf I u. III, Litzlberg Süd, Seewalchen; Mondsee: See am Mondsee.

was the discovery of a hilltop settlement dating to the 4th and early 3rd millennium BC just north of lake Attersee at Lenzing. For the first time in Austria, we have knowledge of a hinterland settlement contemporaneous with the lakeshore sites. The underwater excavations have uncovered likely evidence for settlement activity in the lacustrine zone already in the 5th millenium BC, indications for human activity in 6th mil. BC and are beginning to shed light on the settlement dynamics of the 4th mil. BC (Pohl 2015, 2016). With the start of the Beyond Lake Villages project the excavations were expanded through closely integrated landscape archaeology analysis and palaeoecological research.

Tracing visual patterns, landscape connectivity and site location choice

Our approach is based on four work packages: i) landscape classification, ii) site catchment analysis, iii) LiDaR prospection, and field survey, iv) diachronic analysis. This allows us to address different spatial scales from site level to landscape level. Here we present preliminary results of our landscape work with a focus on visual patterns, connectivity of the landscape and site location choice.

Visibility patterns on landscape level

Shoreline and waterbody must be considered as landscape elements of special meaning, one representing the settlement zone and the other a potentially important resource space in terms of subsistence, communication, and mobility. Therefore, we were interested in characterizing the visual landscape as seen from the shoreline and the lake on a more global level. We turned to cumulative viewshed calculations, a type of visiblity mapping, that consists of generating, and combining large groups of viewsheds (Gillings 2015). This approach offers a powerful set of tools to explore visual patterns on a global landscape scale allowing e.g. to explore prominence and hiddenness in a more systematic way (Gillings 2015; Verhagen 2018). One of the challenges of this approach however lies in the high requirements of computation time and data volume for even small surfaces.

We calculated cumulative viewsheds based on the shoreline and the middle line of lakes Attersee and Mondsee (Figure 3). The processing extent was limited to our research area. The analysis were carried out in ArcGIS 10.1. The basis for the visibility calculations was a 10 m DEM, observer points on the shore lines were extracted from Open Street Map data (Open Source Lake Polygons; one point every 50 m). The obersever height was set to 1.5 m. For our first level of explorative viewshed investigation we deliberately chose a very rough database to reduce computation time and data volume.

The viewshed map reveals for lakes Attersee and Mondsee a rather restricted field of vision, limited in the alpine part of the lakes by steep mountain ranges and in the alpine foreland by morainic walls (Figure 3). Only few of the areas lying beyond the directly adjacent mountain ranges and morainic hills are visible from the lake and the shoreline. Respectively only few areas in this space allow for a larger field of vision. The

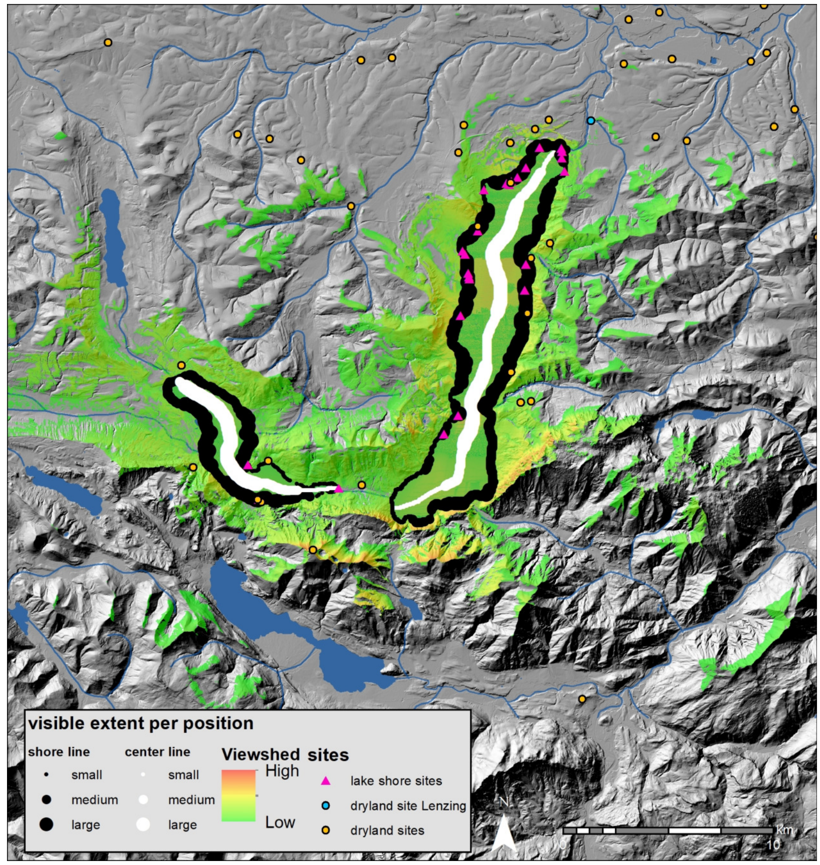

Figure 3: Combined cumulative viewshed map for lakes Attersee and Mondsee with all known lacustrine sites. Calculations are based on a 10 m DEM. Data source: Land Oberösterreich, CGIAR-CSI, Geofabrik GmbH and Open Street Map contributors. Map author: Julia Klammer.

visual landscape can be characterized as a closed world dominated by landscape elements such as the waterbody of the lake, mountain ranges, and moraines as well as areas of high visual connectivity. Seen on the level of the research area lakes Attersee and Mondsee, despite their size, do not represent important or even dominant visual elements. Also, the visual connectivity between the lake/shore area and the adjacent dryland areas, and particularly the alpine foreland, is low.

Putting these observations in relation with the spatial distribution of the 4th mil. sites shows that no site overlooks both, the lake and the wider hinterland area. The majority of the sites is located in the shore area of lakes Attersee and Mondsee and thus within the small world visual landscape described above. All other sites of this time period, and especially the newly discovered settlement located in Lenzing, have no visual connection with any of the lakes (waterbody or shore area). This also means that the 4th mil. settlement of Lenzing has no line of site with any of the settlements in the shore area of lake Attersee. To explore the influence of erosion on the visibility of the site, we performed further visibility analysis which aimed to determine the minimum height needed to be within the visibility range. These showed that at least 16 m of additional height on the spurn were necessary to come within view of the lake. Considering the low number of known 4th millenium dryland sites in the research area, we cannot rule out that the observed patterns are due to filter processes and the state of research. But we can demonstrate through diachronic comparison that positions allowing for an oversight of the lakes and the wider hinterland were not generally avoided during prehistory in the research area. This type of mapping also allows for a systematic exploration of the landscape in terms of zones of prominence and seclusion. In our current work we focus on assessing the prominence and hiddenness of landscape elements of special interest such as natural pathways leading into the lakes as well as places of potential strategic value, e.g. overlooking natural pathways such as the region of Strass im Attergau.

Natural pathways and landscape connectivity

Mobility of neolithic communities has received growing attention over the last years (Leary and Kador 2016). The narrative has shifted from the idea of a static and unmoved sedentism to communities and individuals involved in complex mobility patterns. The lacustrine neolithic of the 4th millenium offers a great wealth of data on mobility patterns from local to supraregional level. We are especially well informed on the processes taking place on the site level in the region of the circumalpine lakes in France, Switzerland and Germany. The period stands out as one of intense mobility with a well documented settlement history characterized by short-lived settlements and varied subsistence strategies affording the managment and cultivation of very different landscape elements and on different spatial scales (Ebersbach 2013; Hafner and Suter 2003; Jacomet et al. 2016; Petrequin 2013; Schlichtherle 2011; Schlichtherle et al. 2004; Hafner, et al. this volume; Mainberger et al., this volume). On a supraregional level farreaching trade and communication networks are evidenced through e.g. the widespread distribution of the so called Mondsee copper.

At the present state of affairs the Mondsee group seems to fit well into these patterns. In certain aspects it shows especially strong indications for the connection with transregional networks. The role of the Attersee-Mondsee region as a hub for transregional communication and trade was discussed, controversially early on (Beninger 1961, pp. 148–153; Childe 1947, p. 291; Franz 1928, pp. 8–12, 299–307; Willvonseder 1963). And as recent research on the provenance of the Mondsee copper has shed new light on the material flows in the area (Frank and Pernicka 2012), the question of the status of this region and the Mondsee group within the transregional networks of this period remains a valid one. We aim to contribute to these questions through spatial analysis by assessing the accessibility and connectivity of the landscape within the research area and its connection to transregional pathways. A glimpse at the map shows that the research area has a potentially high connective value (Figure 1, Figure 2). It links two important natural environments with different resources and environmental conditions, the Alps and the alpine foreland. And it is characterized by a dense hydrological network. Rivers and lakes represent important natural pathways. Whereas the region's larger lakes represent pathways of foremost local and regional importance by connecting the lakeshore communities and the alpine with the forealpine zone. The rivers, especially the Ager (efflux of lake Attersee), connect the region through the Traun river to the Danube valley. It is important to note that the entire region drains to the north (see above). Mobility to the south into the alpine area and beyond can only intermittently make use of waterways via the lakes and is mainly connected to land transport. One important aspect in assessing the connectivity of a landscape is to consider combined land-water-transport. Recently Martin Mainberger

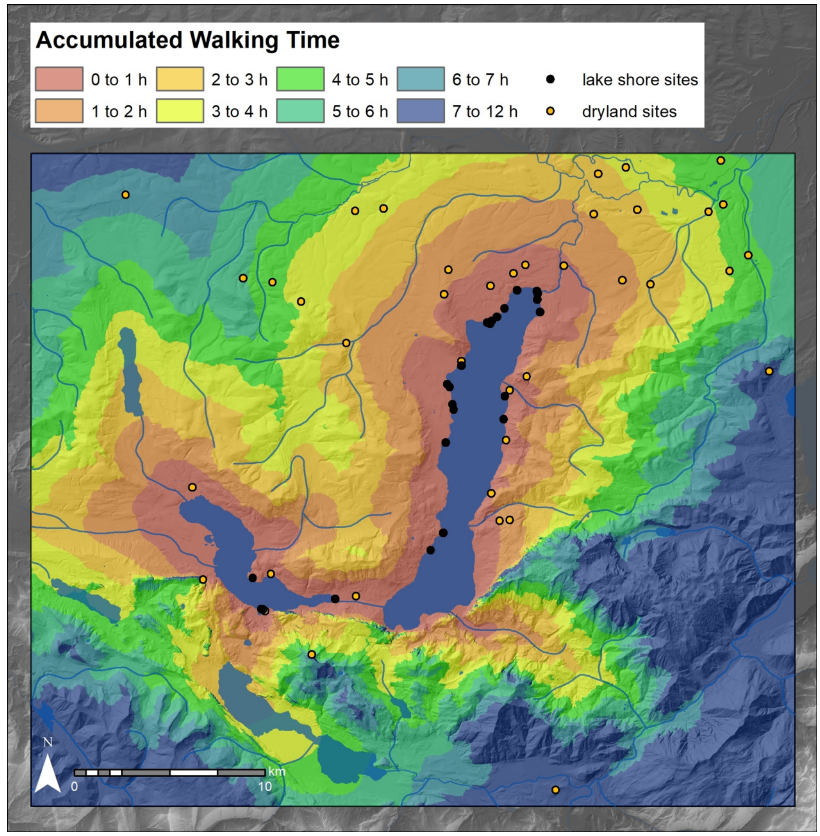

Figure 4: Cost surface map with all known lacustrine sites. Walking time was calculated from the shoreline of lakes Attersee and Mondsee with all known lacustrine sites. Cost distance calculations are based on a 10 m DEM, W. Tobler off-path. Data source: Land Oberösterreich, CGIAR-CSI, Geofabrik GmbH and Open Street Map contributors. Map author: Julia Klammer.

has adressed this topic by looking at the question of prehistoric portage activity across the European watershed in the Federsee region in southwestern Germany (Mainberger 2017).

To investigate the accessibility of the landscape in the Attersee-Mondsee region we used cost surface (dryland) and walking velocity calculations (dryland and water). This type of landscape classification and visualization is especially informative in areas with strong relief differences. The cost surface calculations were based on a 10 m DEM and started from the shore line of lakes Attersee and Mondsee. The processing extent was limited to our research area. For the calculation of the cost distance we used W. Tobler's function for off-path walking. The analysis were carried out in ArcGis 10.1. First and foremost the cost surface map highlights the differences in the relief (Figure 3). The steeper the terrain, the less ground can be covered in a certain amount of time. The smoother and less steep areas in the alpine foreland allow to cover considerably more ground on foot than the alpine areas. On lake Attersee the lacustrine sites cluster in this zone, but do not absolutely avoid steeper areas. Here the visual limit discussed above is reached in far under 60 min walking time. (The dryland settlement site in Lenzing can be reached in less than two hours from the northern end of lake Attersee.) The site of Scharfling on lake Mondsee connects easily to the more alpine lake Wolfgangsee within a two to three hour walk. Not only does this widen the site's hinterland to another lake but it also sets it up as a potential traffic node. Walking velocity also targets accessibility of the landscape, but here we have taken into account land and water travel. This form of landscape characterization highlights corridors that are characterized by flat terrain or water

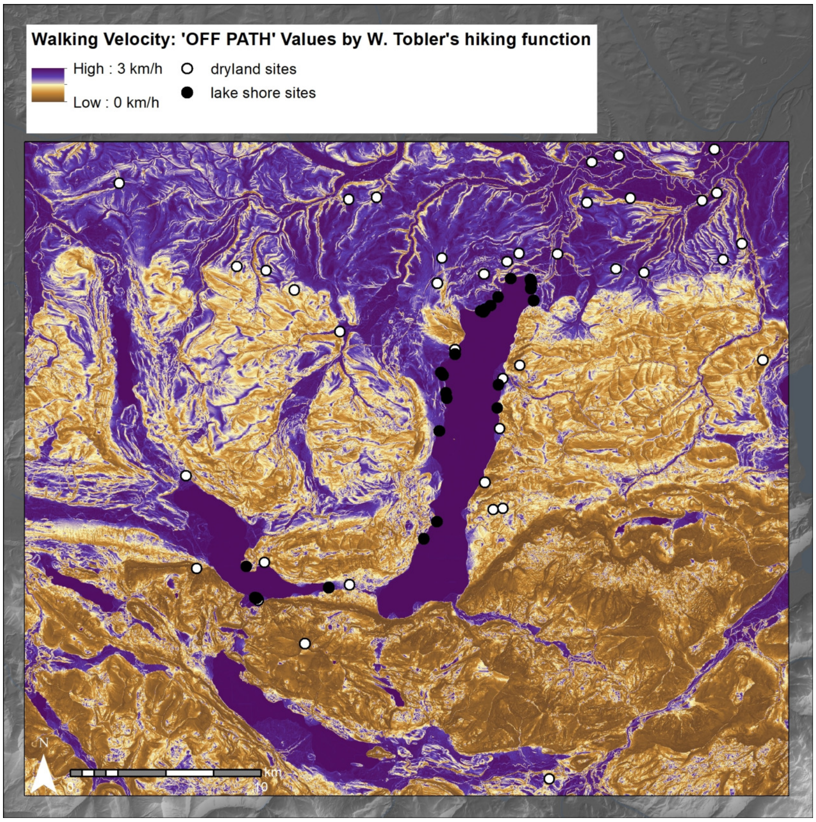

Figure 5: Walking velocity map with all known lacustrine sites. Calculations are based on a 10 m DEM. Data source: Land Oberösterreich, CGIAR-CSI, Geofabrik GmbH and geoland.at. Map author: Julia Klammer.

bodies or zones where both are connected (Figure 5). It also draws attention to areas of potential strategic value in terms of mobility control, such as the area of Strass im Attergau.

Combining the cost surface and walking velocity analysis highlights a potential combined water and land transport corridor connecting the alpine foreland west of lake Attersee with the eastern part of Mondsee via the Wanggau arriving at the site of Mooswinkl on the northern shore of lake Mondsee (Figure 2, Figure 4, Figure 5). Across the lake on the southern shore lies the site of Scharfling which connects via a low lying pass to lake Wolfgangsee and into the alpine landscape. Attention is also directed to another area on lake Mondsee, but for entirely other reasons. The western part of lake Mondsee is conspicuously free of lacustrine sites although in terms of topography it is very much comparable to the northern end of lake Attersee. The latter area is characterized by the highest density of lacustrine sites in the research area.

Site location choice (lacustrine sites)

Through our investigations into site location choice for the lacustrine settlements we target land use on the site level, but also aim at addressing inter-site connectivity. These investigations, which were conducted in the course of a Master thesis (Seidl da Fonseca 2019), encompass two work packages: i) site catchment analysis and ii) analysis of visibility patterns.

Site catchment analysis is a useful tool to investigate site location choice, but the approach comes with certain theoretical challenges, that need to be taken into account (cf. Gross and Huber 2018, pp. 261–262). The classical site catchment model as proposed by Vita-Finzi and Higgs in 1970 (Vita-Finzi et al. 1970) was applied several times in lacustrine research (Benguerel et al. 2010, pp. 156–160; Jacomet et al. 1989, pp. 88–89; Winiger 1989, pp. 229–233). But as Eda Gross and Renata Huber have pointed out, the underlying concept of clearly delimited, autonomous, self-sustaining villages is problematic (Gross and Huber 2018). In fact, this model has come under severe criticism in recent years (Röder et al. 2013). A relational network model that focuses on the entire lake area with its adjacent hinterland as settlement and subsistence zone of a networked community has been proposed in its stead (Gross and Huber 2018). This approach is very promising as it allows for a much higher degree of dynamism in modelling land use and settlement history. In view of the proposed change in concept we suggest that the method of site catchment analysis might be operationalized for this new model as well. In fact a conceptual framework combining site level and landscape level perspectives seems well suited to achieve this purpose.

The site catchement analysis for the lacustrine Mondsee group sites is based on catchments determined through cost surface calculations. Within these catchments geofactor analysis will target slope, potential solar radiation and exposition. Land use based on historical maps will be qualitatively described and the relation to natural pathways analysed. Here we will only focus on the catchment sizes.

Catchment areas were calculated for 30 and 60 minutes for dryland and the water surface of the lakes and for dryland only. These calculations are based on a 5 m DEM. To determine the cost distance the off-path algorithm after W. Tobler was used. Speed of movement on water was equated to walking on flat terrain. The water surface was integrated into the catchment area to take into account the potential connectivity of water bodies and to acknowledge their potential territorial and economic importance (Figure 6). It has to be considered that the economic space of a settlement might not be restricted to one lake shore and the adjacent hinterland, but might extend across the water surface to other dryland zones easily reachable by water transport. The analysis shows that the catchment size of the various settlement sites varies, but not in direct relation to the size of the settlement. When the water surface is taken into account the catchment of some settlement sites changes distinctly, giving access to more resources (surface). The largest impact is on the potential connectivity as travel time is massively reduced. Otherwise a pattern known from other lacustrine settlement areas can be observed, especially in the more densely settled zones of lake Attersee, where catchment areas overlap strongly.

Viewsheds were calculated for every settlement site. The viewshed calculations are based on a 10 m DEM with an observer offset of 1,5 meters. The calculations were performed in ArcGis 10.1. In a first step the field of vision of every settlement site was characterized and quantified. The analysis shows that most sites have a wide view over the water surface, but a very restricted one on the land side. The viewshed of the sites is varied. On average the visual range of the sites at lake Attersee is wider than on Mondsee. On Attersee the sites with the widest view are located on the western (area of Abtsdorf) and eastern (Weyregg) shore at about mid length of the lake. Sites in small bays like Kammerl, Unterbuchberg and Kammer I have the most restricted view. For most of the sites even

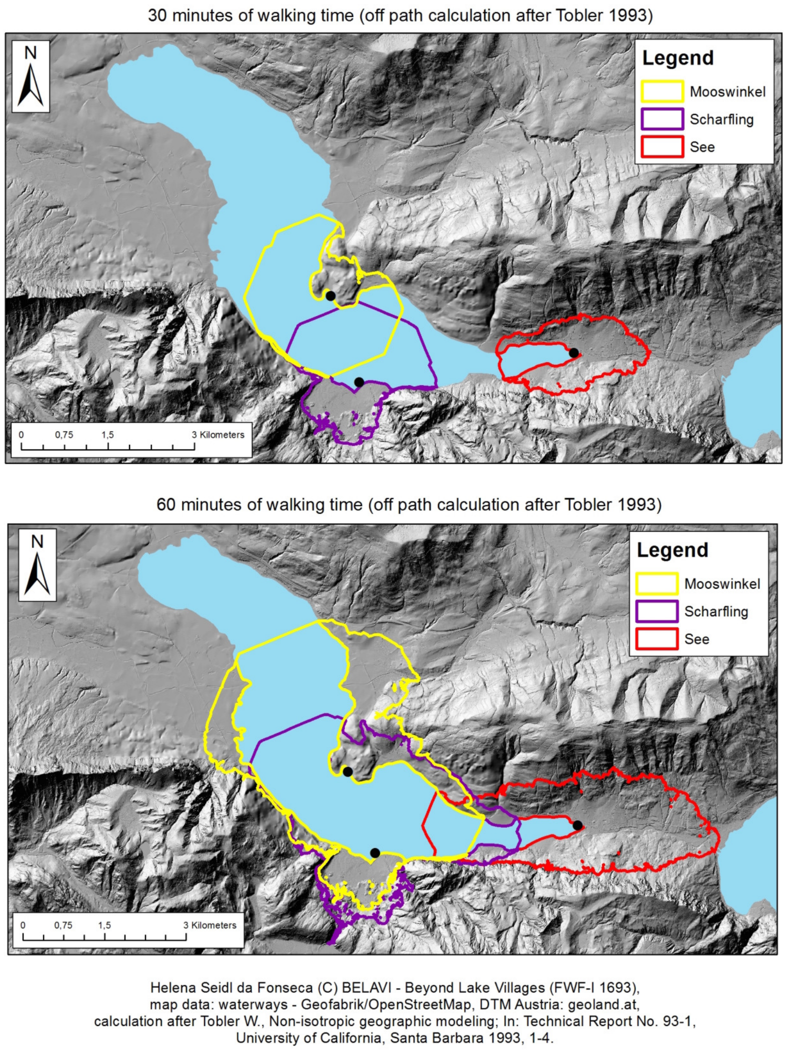

Figure 6: Catchment areas based on walking time (30 min, 60 min) for the lacustrine sites on lake Mondsee. Calculations are based on a 5 m DEM, W. Tobler off-path. Map author: Helena Seidl da Fonseca.

large parts of the terrain within the catchment areas of 30 minutes are not visible. An extreme example is the totally invisible hinterland of the site Litzlberg North I. The sites located at the efflux of the lake Attersee have a good overview of their direct environment, but not further. This of course corresponds to our observations of visual patterns based on the cumulative viewsheds. From a visual 'point of view' the lacustrine sites were more turned towards the lakeside and the opposite shore. Of course these observations are based on individual viewsheds. Cumulative viewsheds based on the catchment area will give a more detailed understanding of the visual landscape around these sites. The question of visual connectivity between the various settlement sites must be approached with caution, as the chronological framework is at present not resolved enough to assess the chronological relation of the settlements. Under the theoretical assumption of all sites being settled at the same time, the settlements of Abtsdorf and Aufham would have been the most prominent or visually the most connective ones. The sites of Misling I and II the least. The sites of Abtsdorf stand out for several reasons, they have the widest viewshed and the highest number of visual contacts with the other lacustrine sites (Figure 7). In addition, they are located in an area where the

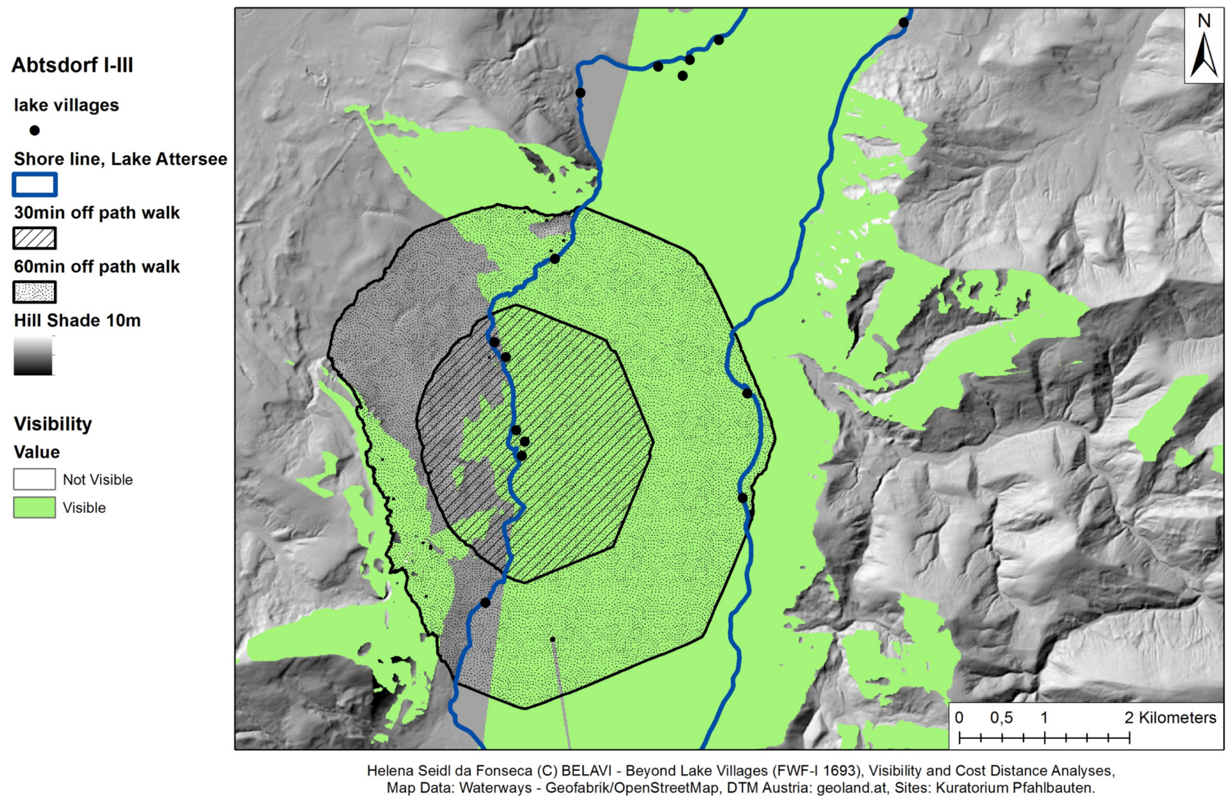

Figure 7: Visibility and cost surface maps calculated for the settlement area of Abtsdorf I-III. Cost distance calculations are based on a 5 m DEM, viewshed calculation is based on a 10 m DEM, with an observer off-set of 1,5 m. Observer point and starting point for the cost distance calculations are set at the center of the combined settlement zones. Map author: Helena Seidl da Fonseca.

relief allows to cover much ground in the hinterland and connect to one corridor of high walking velocity leading into the alpine foreland in the direction of e.g. Strass im Attergau. Current work addresses the quality of the visual range, by classifying the visual field according to Higuchi's classification of foreground, middleground, and background (Wheatley and Gillings 2002, pp. 15–24).

Conclusion

By targeting visual patterns, landscape connectivity and site location choice we are working on characterizing 4th millenium human-environment relations through a 'spatial lense'. The applied methods represent powerful tools in addressing past human landuse, especially as they allow for the combination of different perspectives, such as site level and landscape level. Through the application of the described analysis areas of special topographic properties have come into focus. These need to be investigated further in the field and through diachronic analysis.

Acknowledgements

We would like to thank the Federal State of Upper Austria, the Mayr-Melnhof estate, the Kuratorium Pfahlbauten, the local councils of the Attersee-Mondsee region as well as the grant agencies SNF-DFG-FWF (FWF project number FWF-I-1693).

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Defining pottery use and exploitation of natural products at Clairvaux XIV during the Middle Neolithic

13

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Introduction

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Although organic residue analysis has been applied to archaeological vessels for more than 30 years surprisingly few studies have provided an integrated approach to vessel function (Cramp et al. 2011; Evershed et al. 1997a; Kimpe et al. 2001), partly because of high degree of fragmentation of archaeological ceramic assemblages. Defining pottery function and morphological variability within assemblages is essential to understanding: (i) why pottery was manufactured, (ii) how natural products were processed using such containers, (iii) activities carried out at the site, and (vi) the organisation of prehistoric communities.

The study of organic residues preserved in archaeological pottery provides deep insights into the exploitation of natural resources by past communities (Evershed 2008). The development of chemical analysis of organic residues has demonstrated that animal carcass and dairy products were consumed from the beginning of livestock farming in Anatolia in the Early Neolithic (Evershed et al. 2008). These practices spread from the Near East across Europe with the development of Neolithic (Copley et al. 2005b; Craig et al. 2005, 2011; Cramp et al. 2014a,b; Debono Spiteri 2012; Debono Spiteri et al. 2016; Regert et al. 1999; Salque et al. 2012; Salque et al. 2013). Beeswax, and hence evidence of bee product exploitation and processing, has been detected in a wide range of prehistoric pottery dating to the earliest phases of the Neolithic (Heron et al. 1994; Regert et al. 2001a; Regert et al. 1999; Roffet-Salque et al. 2015). Lipid residues of aquatic resources have been detected at the Mesolithic-Neolithic transition (Craig et al. 2011; Cramp et al. 2014a; Heron et al. 2015), while the evidence for plant processing remains scarce during this period, except at some Mediterranean sites (Debono Spiteri 2012; Šoberl et al. 2014).

Characterising absorbed organic residues extracted from a vessel is only one aspect of understanding its use, as intended and actual function must also be examined (Sigaut 1991). To achieve this, it is important to consider the shape (including capacity, stability, accessibility, and transportability) and physical properties (thermal and mechanical) of the vessel which help to define *intended use* (Rice 1987, pp. 224–226; Skibo 2013, pp. 28–51). Traces of sooting and carbonised deposits, use-wear damage and contents provide information about *actual use* (Rice 1987, pp. 232–236; Skibo 2013, pp. 63–181). In the last few years, some studies have attempted to determine pottery function by combining chemical analysis of vessel contents (characterisation of natural substances, concentration and distribution of lipids, molecular markers of heating) with ceramic morphology (Copley et al. 2005a; Evershed et al. 2003; Heron et al. 2015; Salque et al. 2012; Šoberl et al. 2014), mechanical properties of vessels (Nieuwenhuyse et al. 2015), or thickness of pottery walls (Craig et

Drieu, L., S. Mirabaud, M. Roffet-Salque, T. Blasco, P. Pétrequin, A.-M. Pétrequin, R.P. Evershed, M. Regert (2020). 'Defining pottery use and exploitation of natural products at Clairvaux XIV during the Middle Neolithic'. In: *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Ed. by A. Hafner, E. Dolbunova, A. Mazurkevich, E. Pranckenaite and M. Hinz. Open Series in Prehistoric Archaeology 1. Bern and Heidelberg: Propylaeum, pp. 251–274. DOI: 10.11588/propylaeum.714

al. 2015). Relatively few studies have integrated the full range of available approaches, i.e. morphological classification, morphometric measurements, chemical characterisation of the content, and use-wear analysis (Fanti et al. 2018; Urem-Kotsou et al. 2002; Vieugué 2010). In most cases, the differential preservation of the molecular and ceramic records has prevented a complete and efficient functional study. Only specific use of particular shapes have been highlighted: sieves for dairy products (Salque et al. 2013), pedestal dishes (Šoberl et al. 2014), and cooking pots (Fanti et al. 2018; Salque et al. 2013) used for carcass product processing, *mortaria* for plant and animal product processing (Cramp et al. 2011), and vessels used as lamps (Copley et al. 2005a; Evershed et al. 1997a; Evershed et al. 1997b; Heron et al. 2013). Understanding the function of a whole ceramic assemblage via integrated analysis thus remains an unrealised goal since extensive and well-preserved ceramic material is needed, including both vessel profiles and well-preserved lipids trapped in the porous walls of ceramic vessels.

The *Néolithique Moyen Bourguignon* (NMB) group settled in eastern France, in the region extending from Belfort to Lyon and from Eastern Burgundy to the Western side of Neuchatel Lake between c. 4000/3900 and 3600 B.C. This culture has mainly been defined based on the characteristics of its ceramic assemblages, which are readily differentiated from the older and contemporaneous sites in the region (Michelsberg, Munzingen, Chasséen, and Cortaillod). Recent excavations at the lacustrine site of Clairvaux aimed at complementing our understanding on the NMB culture using ceramic studies. Thousands of vessels were excavated in this lake dwelling site and preliminary analyses of pottery from this and similar lake sites have shown the preservation of lipids to be quite exceptional (Mirabaud et al. 2007; Regert et al. 1998; Regert et al. 2001b, 2003b; Spangenberg et al. 2006). Vessel shapes were previously reconstructed by refitting sherds (P. Pétrequin et al. 2016). Combining typological and morphometric analyses, macroscopic identification for heating evidence, and organic residue analysis from pottery is thus a unique opportunity to investigate ceramic function and use at Clairvaux XIV and to better understand the NMB culture.

Herein, we report the investigation of pottery function at Clairvaux XIV, using molecular and isotopic analysis of lipid extracts, morphology and volume of the vessels, and evidence of heating.

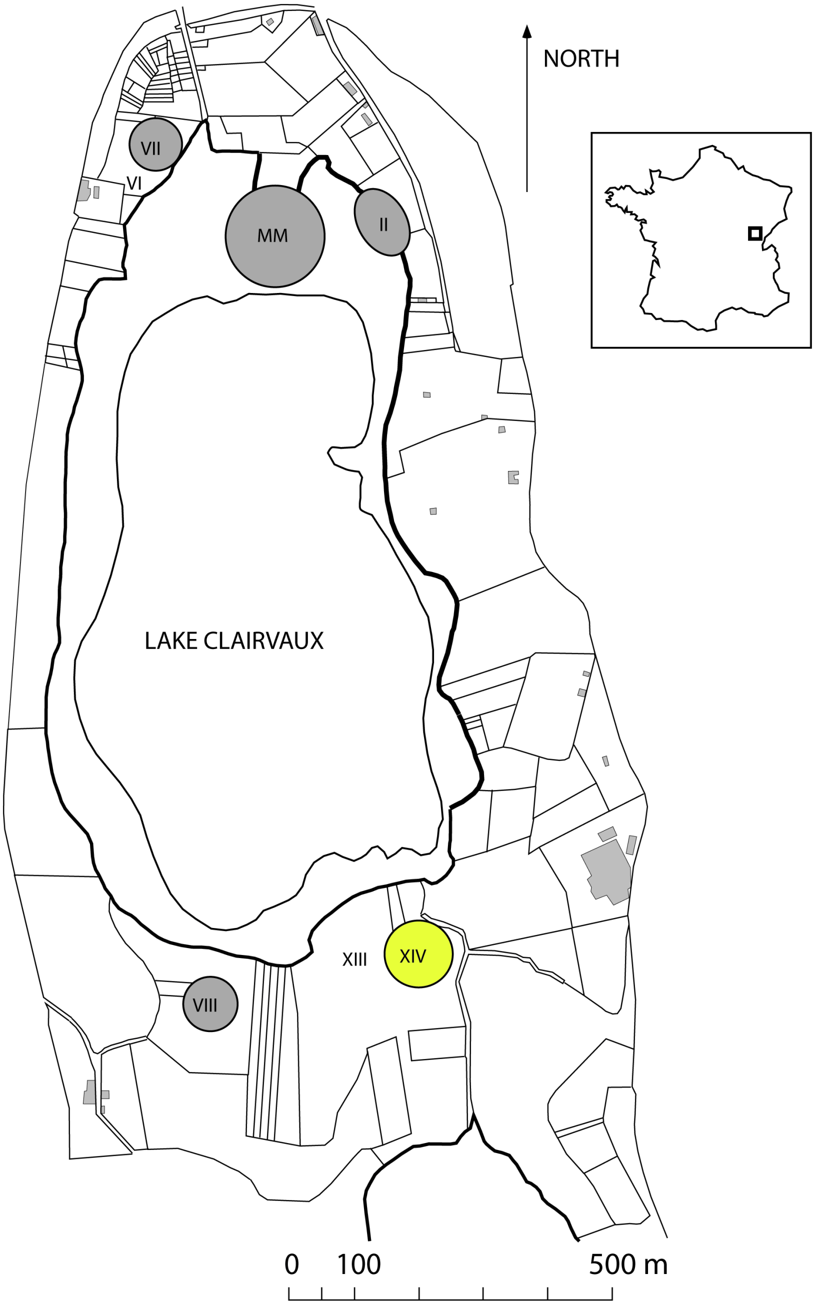

Figure 1: Map of lakes Clairvaux (geographic location in France, and position of the sites around the lake).

Materials and methods

Typological classification, macroscopic observation and morphometric study

In order to fully characterise pottery function at Clairvaux XIV, systemic analyses were performed. A total of 397 out of 440 ceramic vessels (Supplementary information: List of vessels from Clairvaux XIV) recovered from archaeological excavations at the site of Clairvaux XIV were classified in 15 typological categories (Figure 2; P. Pétrequin et al. 2016) and observed visually in order to identify evidence of heating, such as traces of soot and/or charred surface residues (Skibo 2013, p. 63).

Wherever possible, each vessel was characterised using the most relevant criteria applied in morphometric studies: height, maximum diameter and opening diameter (Rice 1987, pp. 224–226; Smith 1988). Volumes were also calculated for all the complete profiles using the application developed by the Archaeological Research Centre of the ULB (Engels et al. 2009). An estimation of minimum volume was made for vessels with incomplete profiles. All these measurements were used to highlight vessel *capacity*, *accessibility,* and *transportability* (Rice 1987, pp. 224–226).

Sampling for lipid analysis

A total of 95 potsherds (Supplementary information: List of vessels from Clairvaux XIV) were selected from the entire assemblage of 397 pottery vessels. Care was taken to ensure this sub-sample reflected the overall

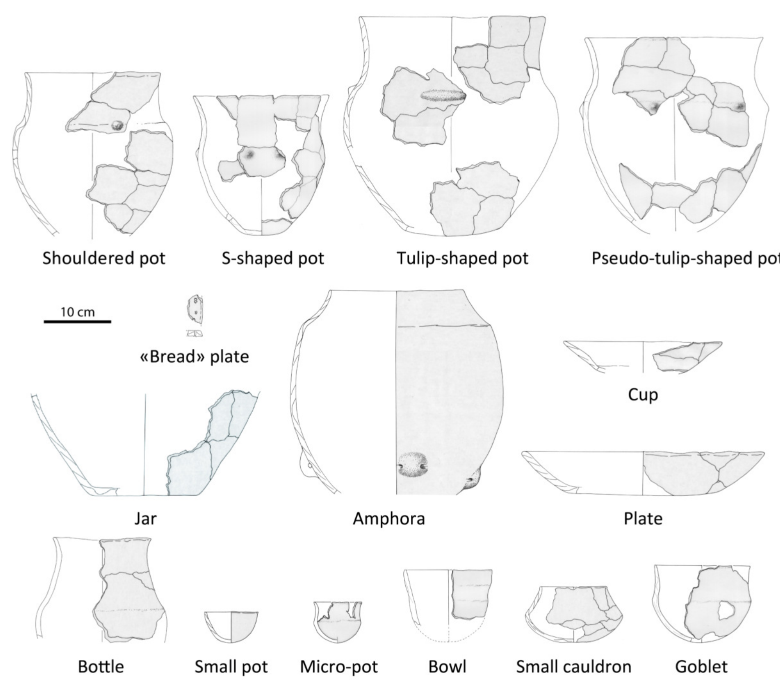

Figure 2: Typological categories from Clairvaux XIV. Drawings A.-M. Pétrequin.

assemblage diversity by taking into account the typology, distribution, dimensions, presence, or absence of charred surface residues on the vessels. A total of 33 thick surface residues were also analysed. For each selected vessel 2 g of potsherd were sampled, preferentially from the body of the vessels, as they have been shown to contain relatively high concentrations of lipids (Charters et al. 1993b, 1997; Evershed 2008). Where possible for shallow containers, such as cups and plates, samples were taken from the sides of vessels.

Extraction of absorbed lipids and molecular and isotopic analyses

Instrumental analyses (HT-GC, HT-GC/MS, and GC-C-IRMS) were performed in three independent laboratories. Details of extraction and derivatisation procedures and instrument operating parameters are available in Supplementary Information.

Results

Macroscopic observation of charring patterns

Macroscopic evidence for heating present on pottery vessels (soot deposits, fireclouds, and carbonised surface residues) have been recorded to understand ceramic use in cooking or other activities involving fire (Charters et al. 1997; Fanti et al. 2018). Two main groups of vessels were established: (i) ceramics with traces and residues suggesting an intense exposition to fire: mainly pots, bottles, jars and amphorae, and (ii) ceramics with no evidence for heating: mainly micro-pots, small pots, small cauldrons, bowls, cups, and goblets (Figure 5b).

Volume measurements

A broad diversity of volume capacities ranging from 0.02 to more than 25 l was observed in the pottery assemblage from Clairvaux XIV. Some typological groups display a narrow capacity range centred on small (cups, small cauldrons, goblets, bowls) and very small volumes (micro-pots, small pots), while in other groups (shouldered pots, S-shape pots, pseudo-tulip-shaped pots, tulip-shaped pots, amphorae) a wide range of volumes (from 0.5 to more than 25 l) is observed (Supplementary information: List of vessels from Clairvaux XIV).

Compositions and concentrations of lipids

Seventy percent of the potsherds yielded more than 5 $\mu g\ g^{-1}$ of adsorbed lipids, with a maximum of 2,055 $\mu g\ g^{-1}$. Surface charred residues contained between 0 and 3,523 $\mu g\ g^{-1}$ of lipids. The analysis of the Total Lipid Extract (TLE) from these potsherds highlighted a wide molecular composition, including intact acyl lipids (triacylglycerols and wax esters) and their degradation products (di- and monoacylglycerols, and fatty acids). Linear

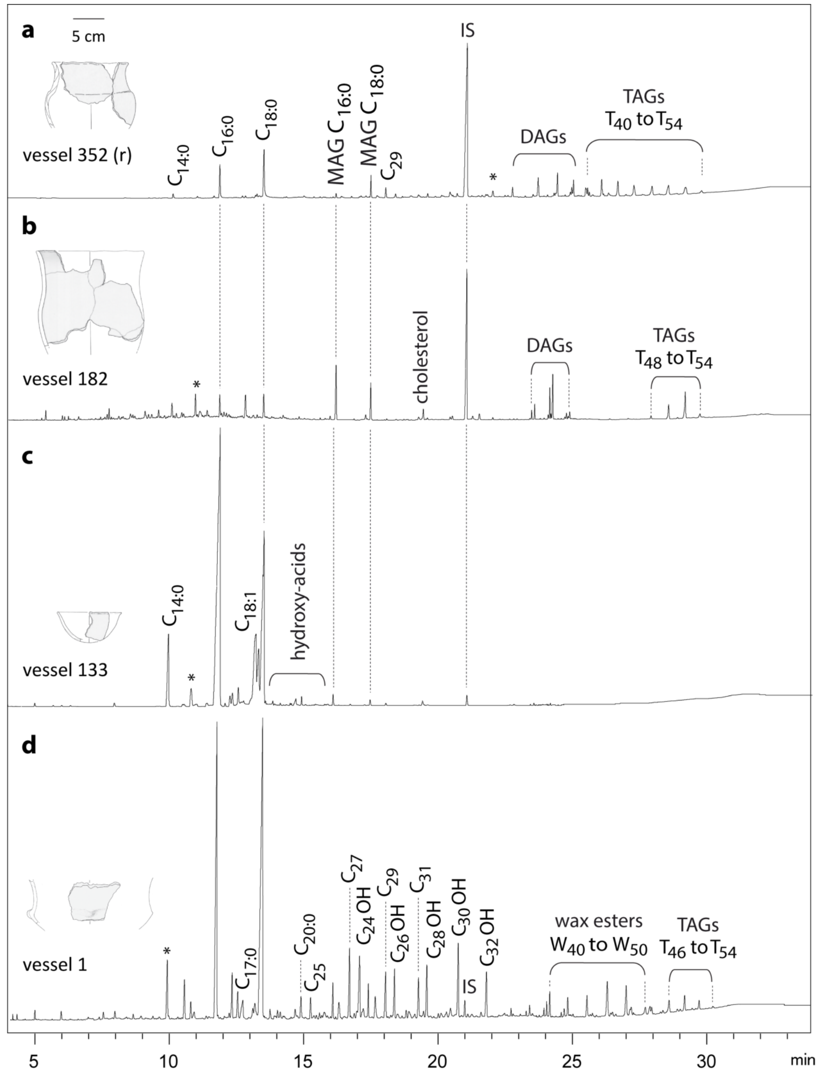

Figure 3: Partial gas chromatograms showing typical trimethylsilylated TLEs from vessels from Clairvaux and containing lipid components characteristic of: (a) dairy products, (b) carcass fat, (c) plant oil, and (d) beeswax.

long chain alcohols and alkanes, sterols, and triterpenes have also been detected. Figure 3 illustrates the diversity of molecular composition by showing typical gas chromatograms of TLE from potsherds from Clairvaux.

Intact acyl lipids were especially well-preserved, with triacylglycerols (TAGs) observed in >30 per cent of the analysed vessels (ranging from 1 per cent to 40 per cent w/w of the TLE). The TAG distributions were characterised by the average carbon number (M) and the dispersion factor (DF; Figure 4) as suggested by S. Mirabaud et al. (2007).

The average carbon number M was calculated using

$$M = \frac{\sum (P_i C_i)}{\sum P_i}$$

where is the relative percentage of each TAG and is the number of atoms of the fatty acid moieties in each TAG.

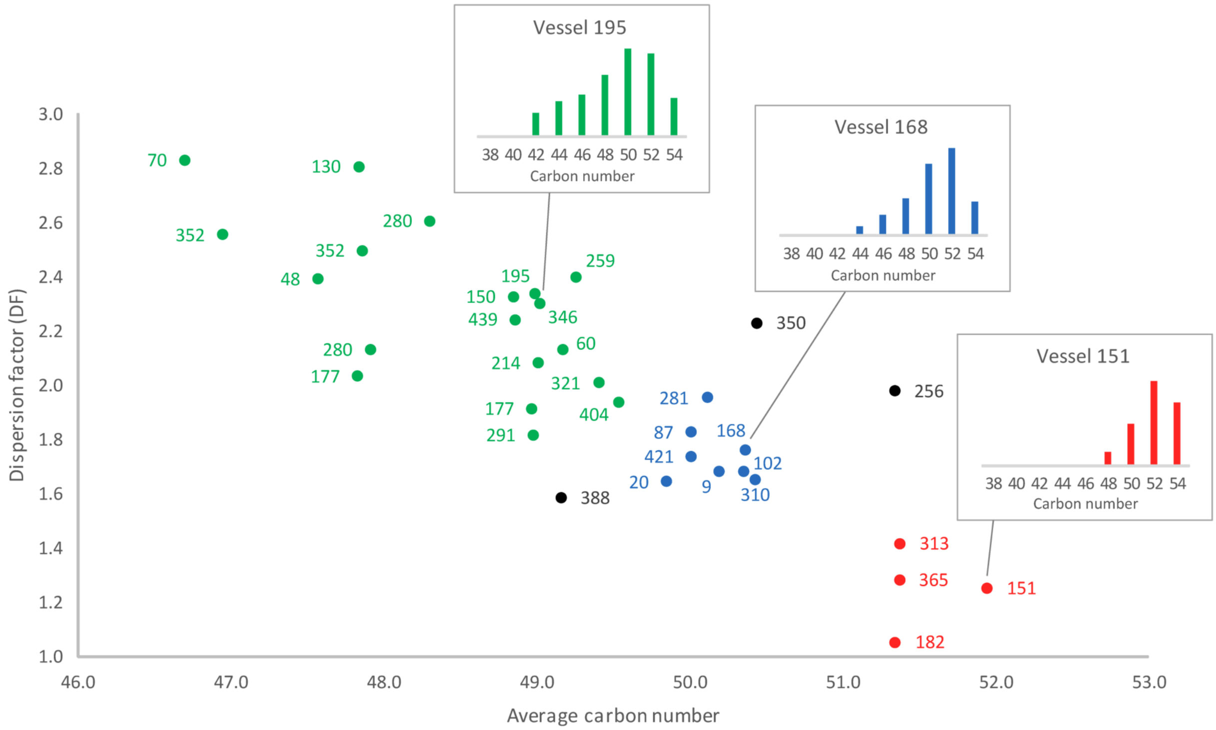

Figure 4: Distribution of archaeological samples based on HT-GC analysis of the TAG distributions: wide distribution (T_{40} to T_{54}) in green, intermediate distribution (T_{44} to T_{54}) in blue and narrow distribution (T_{46} or T_{48} to T_{54}) in red. Samples with unusual TAG distributions are plotted in black. The numbers correspond to the archaeological reference number of the vessels. The inserts are typical TAG distribution for the three groups.

The dispersion factor DF was calculated as follows:

$$DF = \frac{\sqrt{\sum \left((C_i - M)^2 \, C_i P_i\right)}}{\sum P_i}$$

The identification of three main categories made by S. Mirabaud et al. (2007) was confirmed, with wide (T_{40} to T_{54}), intermediate (T_{44} to T_{54}) and narrow (T_{46} or T_{48} to T_{54}) distributions of TAGs. These distributions have been shown to correlate with the origin of the fat.

Subcutaneous animal fats and dairy products

Several criteria were used to distinguish the sources of animal products, including: fatty acid, sterol and TAG compositions, and the carbon isotopic values of the $C_{16:0}$ and $C_{18:0}$ fatty acids. The presence of odd-numbered fatty acids ($C_{15:0}$ and $C_{17:0}$, linear and branched isomers), biosynthesised by bacteria in the rumen of ruminant animals, is indicative of ruminant products (Evershed et al. 1997a; Mottram et al. 1999). Degraded dairy products were characterised based on the fatty acid carbon isotope proxy: $\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$, (Copley et al. 2003), a large distribution of TAGs between $T_{40\text{-}42}$ and T_{54} (Dudd and Evershed 1998), and the presence of cholesterol. Dairy fats were identified based on their wide TAG distribution including the presence of odd-carbon-numbered fatty acids and

Δ^{13}C<-3.1 per mille, in 12 vessels (vessels 60, 70, 130, 150, 195, 214, 259, 321, 346, 350, 352 and 439; Figure 5). The extracts of 5 of the vessels displayed an intermediate TAG distribution (vessels 87, 102, 168, 185 and 421) and 4 vessels contained only traces or no TAGs (vessels 31, 107, 133 and 383; Figure 5), but were identified as dairy fats based on their fatty acid carbon isotope compositions. Dairy products were identified in a further 6 other vessels (vessels 48, 177, 280, 291, 388 and 404) based on their TAG profiles. ESI MSxMS analyses confirmed and clarified the identification of dairy products in 9 of these vessels (vessels 48, 60, 87, 130, 150, 168, 195, 214, 350; Mirabaud, et al. 2007). The δ^{13}C values of $C_{16:0}$ and $C_{18:0}$ fatty acids (Figure 5) allowed the identification of mixtures of dairy and non-ruminant adipose fats (vessel 215) and ruminant adipose and dairy fats, or deer adipose fats (vessels 151 and 256; (Craig et al. 2012)). Hence, dairy products were identified in 26 ceramics, >25 per cent of the vessels investigated.

Degraded animal adipose fats were characterised by a narrow TAG distribution, with ranges between T_{46} and T_{54} (Dudd and Evershed 1998), Δ^{13}C values ranging between 0.3 and -3.1 per mille for ruminant adipose fats and >0.3 per mille for non-ruminant adipose fats (Copley et al. 2003), and the presence of cholesterol. Mixtures of ruminant and non-ruminant adipose fats were detected based on their δ^{13}C values (vessels 30, 46, 180, 188, 313, 388 and 440; Figure 5). Animal adipose fats were identified based on a narrow TAG distribution in 7 vessels (vessels 1, 2, 9, 12, 20, 31 and 185). In vessel 182, the atypical TAG profile largely dominated by T_{52} and the $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$ values indicate a non-ruminant adipose fat origin (Figure 5; Evershed et al. 1997a). Animal adipose fats were thus identified in 15 vessels (16 per cent of the analysed vessels), one of them was characterised as originating from non-ruminant adipose fats while mixtures of ruminant and non-ruminant adipose fats were observed in 7 vessels.

Four samples could not be analysed by GC-C-IRMS, mainly due to mixing with waxy substances, and contained no TAGs to identify securely the natural origin of the fats (vessels 13, 365, 416 and 432). The high concentration of fatty acids, dominated by stearic acid ($C_{18:0}$) and the presence of cholesterol allows their characterisation as animal fats.

Aquatic resources

ω-(*o*-Alkylphenyl)alkanoic acids (APAAs) resulting from alkali isomerisation of polyunsaturated fatty acids occurring during heating were detected in eleven vessels (vessels 30, 46, 130, 195, 214, 215, 256, 313, 388, 421, 259). As C_{20} and C_{22} polyunsaturated acids rarely exist in plant oils but are well distributed in marine and freshwater fats, C_{20} and C_{22} APAAs are thus considered as being biomarkers of aquatic product processing (Evershed et al. 2008; Hansel et al. 2004). C_{20} APAAs were identified in low concentrations in eight vessels (vessels 30, 46, 130, 195, 214, 215, 313, 421; Figure 6), but no C_{22} APAAs were identified. The weak presence of C_{20} APAAs points to the processing of aquatic resources although the evidence is relatively scarce. Since the carbon isotopic composition of the fatty acids from these extracts are not characteristic of freshwater organism products (Cramp and Evershed 2014; Outram et al. 2009), mixing with terrestrial fats is very likely. In fact, due to the low concentration of fatty

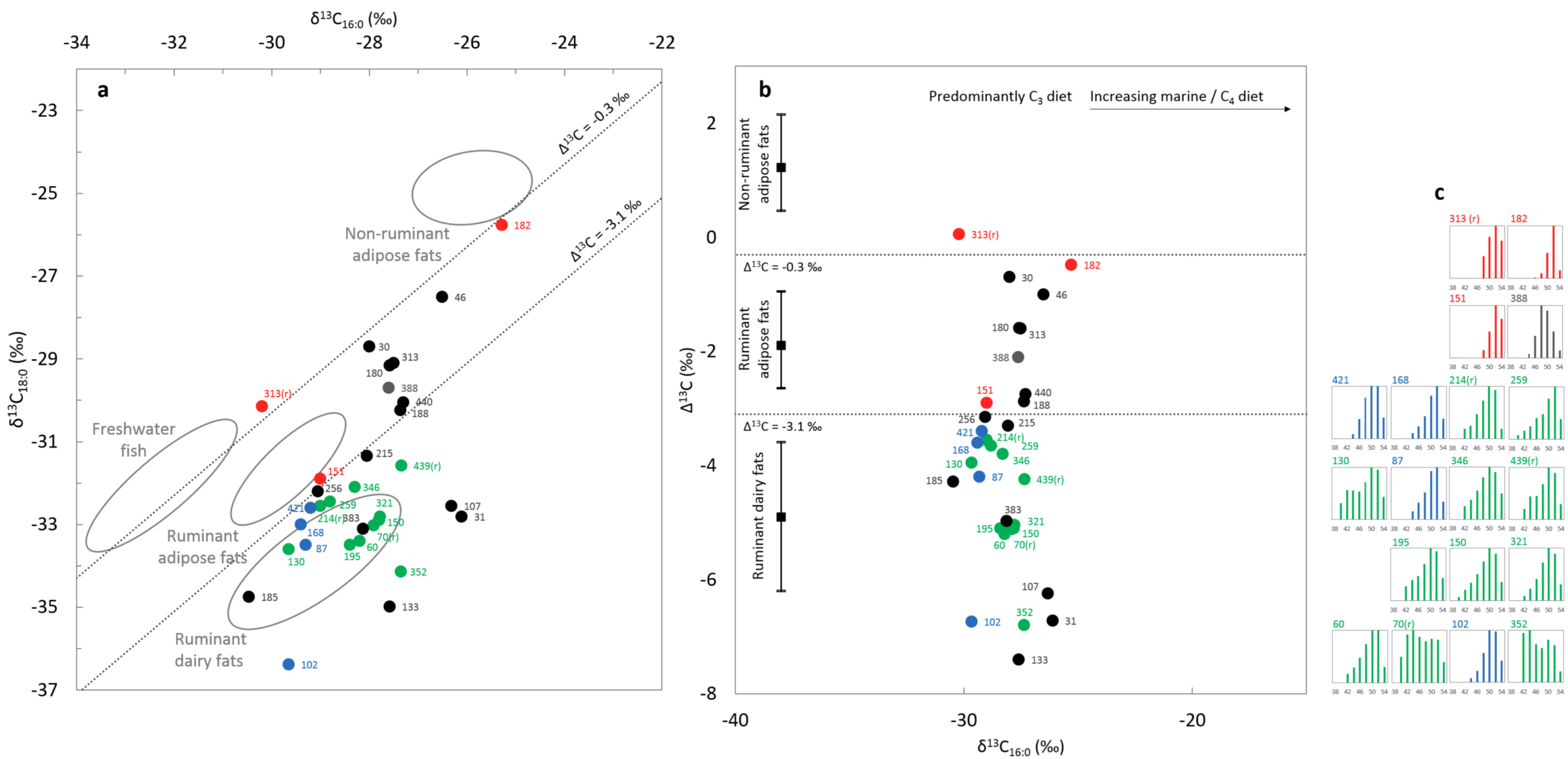

Figure 5: (a) δ^{13}C values for the C16:0 and C18:0 fatty acids of TLEs from Clairvaux XIV (the numbers correspond to the archaeological reference numbers of the vessels, (r) indicates a carbonised surface residue). Ellipses correspond to the δ^{13}C values of reference animal fats obtained from animals raised on a strict C3 diet in Britain (Copley, et al. 2003), and freshwater fish from Kazakhstan (Outram et al., 2009); (b) δ^{13}C values (δ^{13}C18:0 - δ^{13}C16:0) of the same samples from Clairvaux XIV plotted against their δ^{13}C16:0 values; (c) TAG distribution of the corresponding samples. Red and grey plots: narrow distribution of TAGs (T46-48 to T54), blue plots: medium distribution (T44 to T54), green plots: large distribution (T40-42 to T54; Figure 4 for TAG distribution groups).

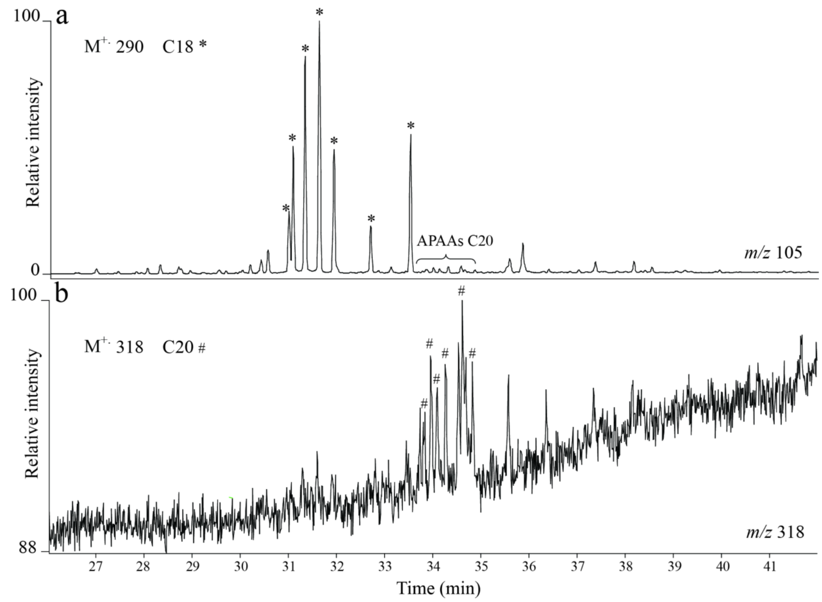

Figure 6: Mass chromatograms of (a) *m/z* 105 and (b) *m/z* 318 for vessel 214 (carbonised surface residue), showing C_{18} and C_{20} APAAs.

acids in freshwater fish compared to mammals, the isotopic signal from these fatty acids can be easily masked by the presence of fat-rich animal foodstuffs (Gunstone 2007). Furthermore, unusually high concentrations of $C_{20:1}$ fatty acids in two samples (vessels 180 and 188) could be linked to freshwater products (Heron et al. 2015), but no APAAs were detected in these samples. Five of the vessels containing APAAs up to C_{20} (vessels 21, 130, 195, 214 and 421) displayed $\Delta^{13}C$ values below -3.1 per mille (Figure 5) and are thus identified as dairy products. One sample (188) was interpreted as a mixture between ruminant and non-ruminant fats based on its carbon isotopic composition ($\Delta^{13}C$ value close to -3.1 per mille). The molecular and isotopic signal for freshwater product processing is thus very low in the ceramic vessels and it could be linked to an occasional processing of freshwater products in pottery vessels, swamped by the use of ceramic containers for cooking terrestrial animal products at Clairvaux.

Plant oils

Plant oils were identified by the presence of $C_{16:0}$ fatty acids in much higher concentration than $C_{18:0}$ fatty acids together with high proportion of $C_{18:1}$ (vessels 36, 133, 188, 216, 259, 267, 425). Further evidence for plant oil was obtained through the identification in some vessels of degradation markers of unsaturated acids (Copley et al. 2005b). Hydroxy- and dihydroxy- carboxylic acids ($C_{18:0}$ and $C_{20:0}$; vessels 133 and 188), diacids ($C_{8:0}$, $C_{9:0}$, $C_{10:0}$, $C_{11:0}$; vessels 36, 216, 267, 404, 425) and C_{18} APAAs without C20 APAAs (vessels 256, 259, 388, 421) were detected in a total of 11 vessels. Series of long-chain alkanes with odd-over-even chain lengths predominance (C_{25}-C_{31}) and a distribution maximising at C_{29} or C_{31} and alcohols (C_{24}-C_{30}) were detected in some TLEs (vessels 9 and 383). 16-Hentriacontanone was present in one extract. Wax ester profile (W_{42}-W_{46}) in which the acyl moiety is composed of both palmitic and stearic acids confirmed that vessel 9 had contained waxy plant-derived material (Ribechini et al. 2008). Unfortunately, the source of oily and waxy plant products was not determined as no specific biomarkers exist for the plants identified in the archaeobotanical record from Clairvaux XIV, such as cereals, peas, acorn, hazelnut, linseed, or poppy seed (Schaal and P. Pétrequin 2016).

Beeswax

A total of 10 vessels contained beeswax, which was easily identified through palmitic wax ester characteristic profiles accompanied by series of long-chain alkanes with an odd-over-even carbon number predominance, fatty acids, and alcohols (Heron et al. 1994; Regert et al. 2001a; Roffet-Salque et al. 2015). Degraded beeswax was identified mixed with fatty material, adipose, or dairy products in four vessels (vessels 2, 45, 177, and 280). Alteration of the characteristic molecular assemblage of beeswax may be due to natural degradation or to heat-treatment (Evershed et al. 2003, 1997b; Heron et al. 1994; Regert et al. 1998, 2001a). Exceptionally well-preserved biomarkers of beeswax were identified in several vessels (vessels 1, 12, 20, 190, 281, 310, 324 and 432), indicating that the material was mildly or not heated at all (Regert et al. 2001a), especially when, in addition, the corresponding ceramic vessel did not display any macroscopic evidence for heating.

Birch bark tar

Biomarkers of birch bark tar (lupenone, betulin, allo-betul-2-ene, lupa-2,20(29)lupadien-28-ol; Charters et al. 1993a; Regert et al. 2003a) were identified in only two ceramic sherds (vessels 31 and 416). Birch bark tar was mixed with animal adipose or dairy fats and could have been used to repair or decorate vessels consequently used to process animal products (Charters et al. 1993a; Dudd and Evershed 1999; Mirabaud et al. 2016).

Discussion

Preservation of lipids

Preservation of lipids was expected to be very good due to degradation at the site being limited by the lack of oxygen in the anoxic burial environment. The concentrations of TLE from Clairvaux pottery, together with TAG preservation, are similar to those obtained from other sherds from submerged marine and lacustrine contexts (Craig et al. 2007; Craig et al. 2011; Regert et al. 1999; Spangenberg et al. 2008), but also to more classical contexts.

TAG preservation can also be considered as a marker of vessel use since repetitive episodes of heating of fat-rich products lead to TAG hydrolysis (Choe and Min 2007; Evershed 2008). It thus suggests that TLE with low percentages of TAGs are likely to have been heated repeatedly, even though this point needs to be tested experimentally. Good preservation of TAGs was mainly observed in cups, small cauldrons, small pots, goblets, and microvases (half of these vessels contained between 5 per cent and 40 per cent of TAGs in the TLE). Most of the vessels from this group also presented clear evidence for heating (sooting marks or visible residues).

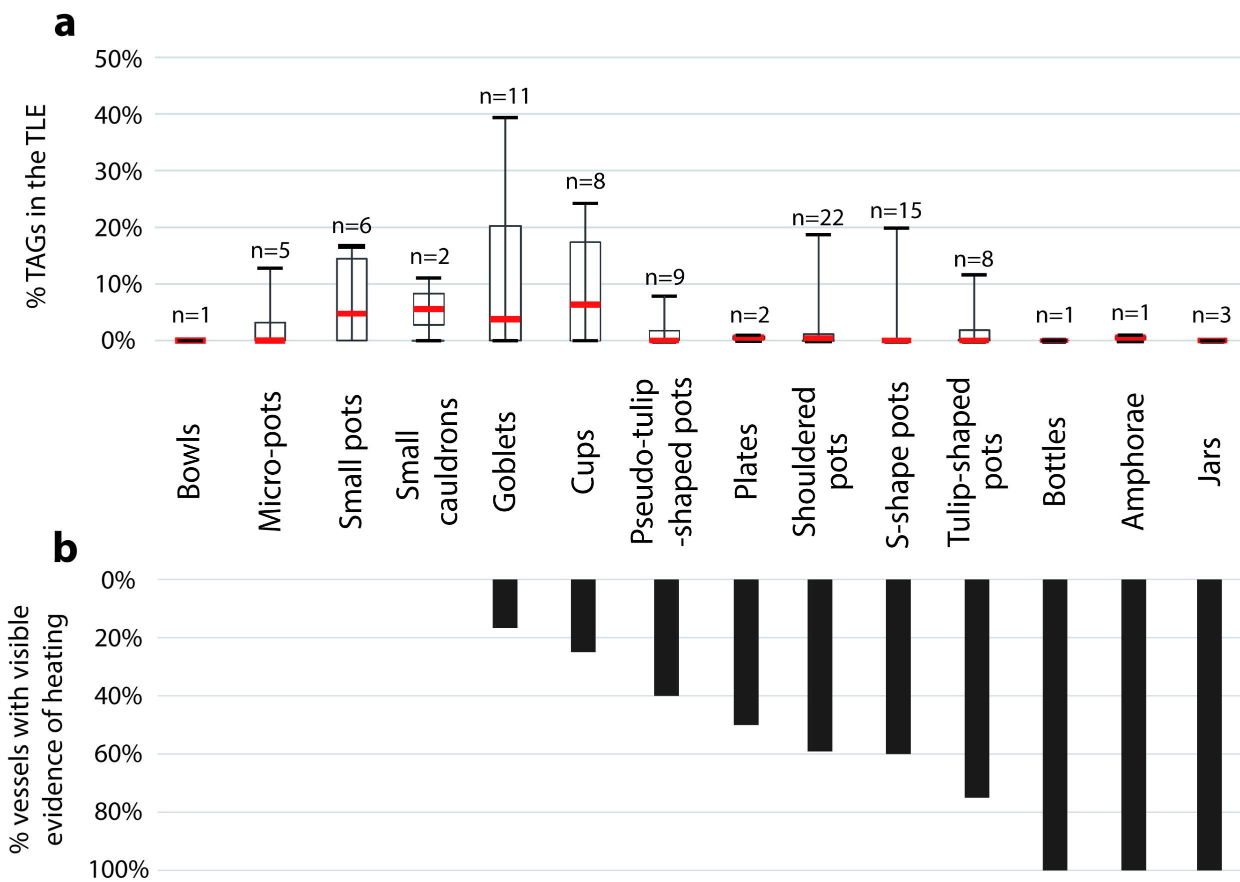

Figure 7: (a) Box plot of TAG percentage in TLEs from absorbed residues (minimum and maximum, median, 1st and 3rd quartiles); (b) percentage of vessels analysed for lipid residues presenting visible evidence for heating (trace of soot deposits or carbonised surface residues) for different pottery typological groups. Please note a correlation between well-preserved TAG distribution and lack of evidence for heating.

Three quarters of the larges pots, bottles, plates, jars, and amphorae contained <1 per cent of TAGs (Figure 7a). Low TAG preservation in these groups correlates well with visible evidence for heating, except for the bowls where both low abundance of TAGs and no evidence for heating were observed.

Functional categories

This work addresses the question of ceramic function by bringing together, morphological shapes, morphometric measurements (volumetric capacity, rim diameter) with evidence of heating (traces of sooting, carbonised surface residues) and organic residue identification for vessel contents. We focused on the most numerous typological categories of ceramics including: shouldered pots, S-shape pots, pseudo-tulip-shaped pots, tulip-shaped pots, small pots, micro-pots, cups, and goblets, which together represent around 80 per cent of the ceramic assemblage. Three main uses of the vessels were identified, with specific subcategories of use defined based mainly on the volume of ceramic vessels (Figure 8).

Pots of less than 1 l capacity (vessels 102, 130, 195, 251, and 352), whether they are shouldered, S-shape, pseudo- or tulip-shaped, displayed charac-

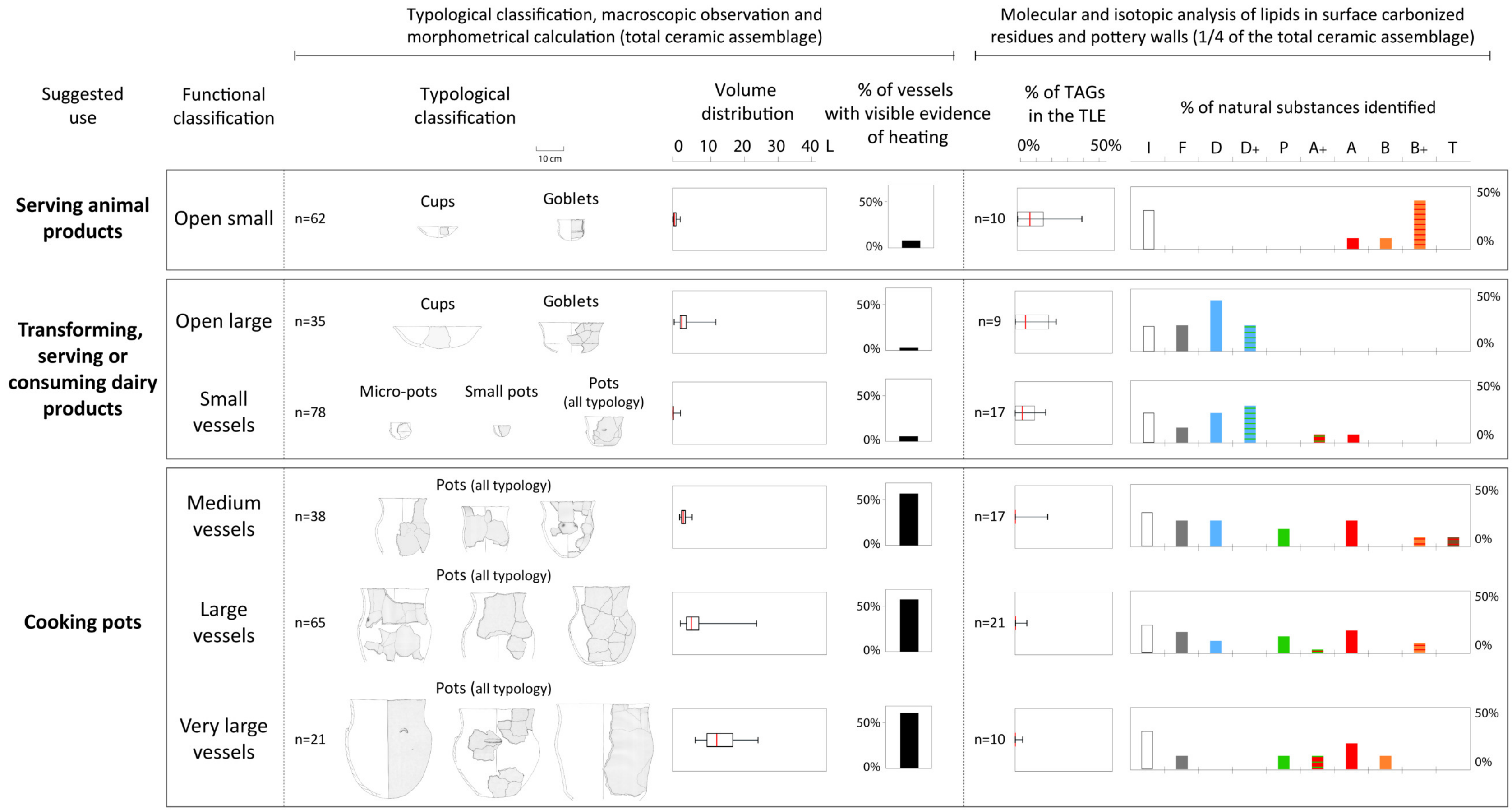

Figure 8: Classification of vessels from Clairvaux XIV and results from the integrated approach (typology, volume calculation, macroscopic observations, and lipid analysis); I: not interpretable; F: fatty products; D: dairy products; D+: dairy products, mixed with plant or freshwater products; P: plant products; A+: Animal adipose fat, mixed with plant or freshwater products; A: ruminant, non-ruminant, deer carcass products, and mixtures of animal carcass products; B: beeswax; B+: beeswax mixed with animal carcass or dairy products; T: birch bark tar mixed with animal carcass or dairy products.

teristics in common with small pots (vessels 150, 269, 273, 346, 382, and 385) and micro-pots (vessels 13, 81, 87, 133, 400). These vessels mainly contained dairy products, either pure or mixed with plant or aquatic oils. Almost 90 per cent of them did not display any traces of heating and contained well-preserved TAG profiles (half of them contained between 4 and 20 per cent of TAGs in the TLE). Furthermore, all these vessels had small or very small capacities: they could easily have been manipulated and handled with only one hand, and thus were likely intended for individual use (Henrickson and McDonald 1983; Smith 1988; Tsirtsoni 2001). Hence, the analyses revealed a new group of small and very small capacities vessels (Figure 8: Small vessels) that were specifically used for dairy products processing, serving or consumption. Other commodities were sometimes mixed with dairy products, maybe to prepare fermented products, such as yoghurt or cheese or to flavour dairy products. The large number of this type of ceramic vessels at Clairvaux XIV (10 per cent of the total assemblage) and other NMB sites, is seen on several sites from the Cortaillod culture, although they are rarely found on contemporaneous sites of the Michelsberg and Chassey cultures (P. Pétrequin et al. 2016). The use of small pots to process or serve milk has also been seen at sites from the British Neolithic (Copley et al. 2005a).

Cups and goblets are both shallow vessels allowing easy *access* to the contents (Rice 1987, pp. 225–226), exhibit similar characteristics, i.e. a wide range of substances was identified in those vessels and they were rarely exposed to fire: traces of soot or visible carbonised residues were rarely detectable on their walls (only 11 per cent of vessels displayed evidence of heating) and hydrolysable lipids (TAGs and esters) were usually well-preserved (the TLE of 50 per cent of these vessels contained more than 10 per cent of TAGs).

Understanding the use of cups and goblets with large rim diameters (vessels 37, 60, 225, 321, 357 and 421) is challenging (Figure 8: Open large) as the TLE from their walls seem to be similar to those from small vessels (dairy products, pure or mixed with plant-derived products, see above). Cups and goblets may have been used to serve dairy products mixed with low-fat commodities (e.g. cereals, fruits) or were used to process dairy products, possibly being used in association with small vessels, for example to collect the liquid whey from the draining of cheese curds (Gouin 1997; Salque et al. 2013).

Cups and goblets with small diameters (<20 cm; vessels 1, 12, 20, 213, 2801, 310, 320, 324, 388, and 391) mainly contained beeswax mixed with animal fats (Figure 8: Open small). Since these products seem to have rarely been heated, beeswax was probably used to waterproof these vessels, which were then used to serve or consume animal-based commodities (Copley et al. 2005a; Šoberl et al. 2014).

Large pots seem to have been regularly exposed to fire: 69 per cent of the pots (shouldered, S-shape, pseudo- or tulip-shaped) with more than 1 l capacities display visible evidence for heating. Furthermore, bases of these vessels are often difficult to reconstruct because of extensive flaking and alteration, probably linked to extended exposure to fire (P. Pétrequin and A.-M. Pétrequin 2016). When considering the molecular assemblage extracted from the sherds, TAGs are rarely detected in these vessels (77 per cent of them have no TAGs in the TLE) and, when present, beeswax molecular profiles are often highly altered (vessels 2, 45 and 117). The alteration of the *n*-alkane profile, hydrolysis of TAGs, and esters can happen during repeated episodes of heating involving water (Choe and Min 2007; Regert et al. 2001b), such as cooking soups and broths or frying water-rich commodities. The shape of these vessels would have been perfectly be suited to extensive boiling as their relatively closed rim prevents excessive evaporation but allows access to the content and facilitates release of steam, preventing the vessel content from boiling over (Henrickson and McDonald 1983; Skibo 2013, pp. 33–34). The high number of large pots excavated at the site (30 per cent of the total assemblage) could be explained by the frequent turnover of these cooking pots weakened by thermal shocks (P. Pétrequin and A.-M. Pétrequin 2016). Since some pots can reach more than 20 l capacities (Figure 8: Very large vessels), it would have been difficult for one person to move the vessel on and off the fire. Such large pots were certainly used to cook commodities for a group rather than for individuals. This wide range of capacities may be interpreted as fulfilling a variety of uses, ranging from family use (medium to large vessels) to community ceremonial use (large to very large vessels), as seen in ethnoarchaeological examples (Skibo 2013, p. 77). A broad diversity of natural substances appears in the residues of these medium to very large vessels, including: dairy fats, animal adipose fats, plant oils, and beeswax, either pure or mixed, with some slight variability depending on the volume (Figure 8: Medium vessels, Large vessels, and Very large vessels). The presence of several substances in the same vessel could be seen as intentional mixing or successive episodes of use. These vessels were thus identified as cooking pots, probably intensively used to cook a wide variety of commodities, as seen in other European Neolithic contexts (Fanti et al. 2018; Salque et al. 2013; Šoberl et al. 2014).

Pure beeswax with a molecular distribution very close to that of fresh beeswax was extracted from a very large vessel (vessel 190, more than 20 l). This pot exhibited no evidence of heating on its outer surface; and thus could have thus been waterproofed with beeswax and used as a storage vessel for water or water-based commodities, or used for storing beeswax itself.

Exploitation of natural products at Clairvaux XIV

Archaeozoological remains from Clairvaux XIV suggest that domestic ruminants have been exploited both for meat and milk (Arbogast 2016). This is reflected in the lipids preserved in pottery vessels through widespread occurrence of ruminant carcass and dairy fats identified using the fatty acid stable isotope compositions and TAG distributions. In contrast, non-ruminant fats were detected in few vessels, although boar and pig skeletal remains are abundant in the faunal assemblage. According to the very high number of bone remains of wild animals and domestic non-ruminants compared to the domestic ruminants, the formers appear to have been the major source of meat in Clairvaux in most of the occupation phases, even when considering meat yield (Lyman 1979; White 1953). Non-ruminant animals could have been processed without pottery, roasted over a fire or heated on stones, as evidenced by the presence of several burnt bones at the site, especially amongst the porcine assemblage (Arbogast 2016).

Molecular and isotopic analyses confirmed the importance of milk exploitation at Clairvaux, supporting herd reconstruction based on the kill-off profiles for domesticates (Arbogast 2016). Dairy products were detected in 25 per cent of the vessels, with specific vessels being dedicated to the processing and consumption, i.e. small vessels and open large vessels. Dairy products thus seem to have been of particular importance for the Neolithic inhabitants of Clairvaux, reflecting trends seen at other Neolithic sites (Copley et al. 2005b; Craig et al. 2015; Salque et al. 2013). Dairy products appear to have been exploited since the beginnings of animal domestication (Debono Spiteri et al. 2016; Evershed et al. 2008) and their consumption has continued over millennia across the European Neolithic, probably because of their nutritional qualities but also because of their relatively non-perishable properties allowing storage through the winter period (Copley et al. 2005a). Milk could have been consumed fresh or mixed and cooked with other commodities (vessels 214, 256, 280) or transformed in other dairy products, such as yoghurt, butter, or cheese. Mixing milk with plant extracts could have been used as an alternative to rennet in cheese production (Egito et al. 2007; Macedo et al. 1993). Plant products could have also been used for flavouring or increasing the shelf-life of dairy products (Guarrera et al. 2005).

Plant oils and waxes were detected in several ceramic vessels, but their molecular distributions are insufficiently diagnostic to determine their natural origins. However, carpological studies revealed that cereals (barley, wheat, durum wheat, einkorn wheat, and emmer wheat), peas, acorns, hazelnuts, linseed, and poppy seeds were available at Clairvaux XIV (Schaal and P. Pétrequin 2016). Exploitation of flax for textile-production can be ruled out since no flax yarn or linen textile has been identified among the well-preserved ropes and woven materials (Schaal and P. Pétrequin 2016). Flax seeds were probably used as a source of vegetable oil, which is extracted by boiling ground seeds (Ertuğ 2000; Marinval 2005, p. 25) as seen on the contemporary sites of the Pfyn culture (Maier and Schlichtherle 2011). Vegetable oil could also have been produced from poppy seeds and hazelnuts. Boiling could have been used to remove toxic tannins from acorns for human consumption with lipid residues being deposited in the walls of vessels as a by-product of this process (Aurenche 1997; Deforce et al. 2009; Saul et al. 2012). Plant oils at Clairvaux were mainly identified in large and very large vessels exhibiting visible evidence for heating (vessels 36, 216, 267 and 425). Such vessels would indeed be particularly suitable for boiling large quantities of seeds. Plant products were occasionally identified together with animal fats (vessels 9, 67, 188 and 440).

Aquatic biomarkers were scarce in the ceramics from Clairvaux XIV, which is surprising considering the lacustrine location of the settlement. Evidence for fishing is seen at contemporaneous sites around the lake Clairvaux based on the presence of fish vertebra and the remains of fishing nets, however, the overall interpretation is that it was an occasional activity, with fishing occurring preferentially on the river. As with many foodstuffs, fish may have been prepared without the use of ceramics, being consumed raw, salted, smoked, or dried. The discovery of the eggs from fish parasites in human faeces from the site, would support the consumption of raw or undercooked fish (Dommelier-Espejo and P. Pétrequin 2016).

Beeswax occurs extensively in the extracts of the Clairvaux XIV pottery vessels, sometimes mixed with animal carcass or dairy fats presenting carbonised surface residues (vessels 2, 45, 177, 280). Residues of beeswax could indicate that honey was used as part of a recipe involving various foodstuffs, as it has also been identified in late Neolithic vessels from Chalain 3 (Regert et al. 1999). In several vessels (vessels 1, 12, 20, 190, 281, 310, 324 and 432), the molecular signal from beeswax is very well preserved, probably because the material had been mildly heated or not heated at all. When detected alone, we can suggest that the ceramics were waterproofed with beeswax or that this product was stored in the vessels. Beehive products are known to have been exploited at least from the beginning of Neolithic since beeswax is attested in numerous ceramic vessels (Roffet-Salque et al. 2015), in particular in contemporaneous archaeological sites in Germany (Heron et al. 1994) and France (Regert et al. 1999). Beeswax was probably obtained from wild beehives in forests surrounding the lake of Clairvaux. Those forests were also highly exploited for other products such as wood (Duffraisse 2016), wild fruits (Schaal and P. Pétrequin 2016), and wild game (Arbogast 2016). Besides a good knowledge of the forest ecosystem, collecting bee products required specific harvesting strategies and skills from the villagers (Mirabaud et al. 2016).

Conclusions

This study of the ceramic assemblage from Clairvaux XIV with both traditional ceramic analysis and organic residue perspective highlights the complex use of pottery vessels during the first half of the IVth millennium BC. Combining macroscopic observation, typological classification, morphometric measurements, and analysis of preserved lipids, using molecular and isotopic approaches, has provided new insights into the society living at Clairvaux XIV.

We have identified a wide range of vessel uses among the pottery assemblage: utilitarian pots used for cooking or processing a wide variety of animal and plant products, small shallow vessels for serving or consumption, and dedicated vessels for milk and/or dairy product processing or consumption. Several other studies of Neolithic ceramic vessels have focused on cooking pots (Debono Spiteri 2012; Dudd and Evershed 1999; Fanti et al. 2018; Šoberl et al. 2014; Vieugué 2010). One study demonstrated the specific use of some vessels for dairy products in comparison to cooking pots (Salque et al. 2013), while in the British Neolithic dairy products were mainly processed in carinated bowls (Copley et al. 2005c; Cramp et al. 2014b; Smyth and Evershed 2016). Most the vessels investigated were thus clearly related to food and culinary or consumption activities.

The diversity of vessel functions seems to have remained constant within the early phases of the settlement, which indicates that the economic activities remained the same through time at Clairvaux XIV (Smith 1988). During the last phases (5 and 6), the percentage of vessels dedicated to dairy products slightly decreases (around 30 per cent of the whole ceramic assemblage during phases 1 to 4, but falling to 22 per cent during phases 5 and 6), reflecting the decline in the importance of small ruminants in the faunal assemblage and the increase of game before the abandonment of the village (Arbogast 2016).

Archaeobotanical (Schaal and P. Pétrequin 2016) and archaeozoological (Arbogast 2016) studies have already demonstrated that agriculture and herding were complemented by forest exploitation (fruit collection, hunting). Our approach completes our understanding of the complex resource management practices at Clairvaux XIV. This study revealed that non-ruminant domestic and wild animals were likely prepared and consumed without using ceramics, a practice highlighted at other Neolithic sites (Craig et al. 2015; Mukherjee et al. 2008; Šoberl et al. 2014). Fishing was an occasional activity at Clairvaux, and as in most Neolithic sites (Copley et al. 2005a; Cramp et al. 2014a; Debono Spiteri 2012; Fanti et al. 2018; Smyth and Evershed 2016; Spangenberg et al. 2006, 2008), aquatic products were rarely processed in ceramics. Dairy products are present at high abundance in the ceramic assemblage, sometimes mixed with plant or aquatic products. Milk was mainly obtained from small ruminants and seems to be of particular importance for the Neolithic people living at Clairvaux XIV. Chemical analysis also revealed that bee products were exploited at the site. Because of the broad diversity of natural products identified in the ceramic vessels, Clairvaux XIV stands apart from other Neolithic sites: only few sites in Italy (Debono Spiteri 2012), Slovenia (Šoberl et al. 2014) and England (Copley et al. 2005a) have revealed the processing of such a wide range of commodities in ceramic vessels. Several complementary hypotheses can account for the wide range of natural products detected in these vessels, particularly the exceptional preservation of organic matter in lacustrine context, the range of potshapes investigated in this study and the diversity and the complementarity of the exploited ecosystems.

Studying the ceramic assemblage from Clairvaux XIV has highlighted the potential of integrating archaeological and chemical analyses in large-scale study of pottery assemblages to unravel their use. Pottery use, activities carried out at the settlements, and evolution of food practices can be investigated using this interdisciplinary approach. Further integrated studies of pottery vessels from other sites from NMB and neighbouring cultures such as Michelsberg, Munzingen, Chasséen, Pfyn, and Cortaillod now need to be carried out in order to understand if these practices were common in the Middle Neolithic sites or if they were specific to Clairvaux XIV. It would be of particular interest to study ceramic vessels from La Motte-aux-Magnins V (Middle Neolithic, around Lake Clairvaux) where clearer evidence of fishing activities has been found. The status of milk and milk products during this period should also be investigated: dairy fats have already been identified in four vessels at Chalain 4 (Late Neolithic, 3040–2950 cal. BC) and sieves appear in this region at sites from the Late Neolithic (Clairvaux III and Chalain) and the Early Bronze Age (La Motte-aux-Magnins; P. Pétrequin 1986). Investigating vessel use of small and very small vessels and cups could bring information concerning the specific use of these vessels in the Cortaillod culture (P. Pétrequin et al. 2016).

Supplementary Information

For this contribution, research data are freely available online at `https://doi.org/10.11588/data/5NSDVM`.

Files:

S1: Devices and parameters. (docx)
S2: List of vessels from Clairvaux XIV. (xlsx)
S3: Results from chemical analysis. (xlsx)

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By collecting the papers presented at the 2016 session of the EAA in Vilnius, this book aims to take this diversity as an opportunity. The geographical scope extends from the Baltic to Russia, Belarus, Albania, North Macedonia, Bulgaria, Bosnia, Croatia, Greece, Germany, Austria and Switzerland to France.

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